STATE OF CONNECTICUT.

TENTH ANNUAL REPORT

OF THE

STORRS

AGRICULTURAL EXPERIMENT STATION,

STORRS, CONN.

1897.

Printed by Order of the General Assembly.

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Publications of the Station.

The publications of the Station will be mailed to all citizens of Connecticut, and to Granges, Farmers' Clubs, and other agricultural organizations who ask for them, and so far as circumstances permit, to those who apply from other States. Requests for publications should be addressed to

STORRS AGRICULTURAL
EXPERIMENT STATION,

TOLLAND COUNTY. STORRS, CONN.

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The Station is located at Mansfield (P. O. Storrs), as a department of the Storrs Agricultural College. The chemical and other more abstract research is carried out at Wesleyan University, Middletown, where the Director may be addressed.

Report of the Executive Committee.

To His Excellency Lorrin A. Cooke,
Governor of Connecticut.

In accordance with the resolution of the General Assembly concerning the congressional appropriations to Agricultural Experiment Stations, and an Act of the General Assembly approved March 19, 1895, relating to the publication of the Reports of the Storrs Agricultural Experiment Station, we have the honor to present herewith the Tenth Annual Report of that Station, namely, that for the year 1897.

The accompanying report of the Treasurer gives the details of receipts and expenditures. We refer you to the report of the Director and his associates for a statement of the work accomplished during the past year. We are confident that the funds have been wisely expended and that the work accomplished is such as will result in great benefit to our agricultural and other interests.

Respectfully submitted,

T. S. GOLD,
W. E. SIMONDS,
B. F. KOONS,
Executive Committee.

Report of the Treasurer

FOR THE FISCAL YEAR ENDING JUNE 30, 1897.

The following summary of receipts and expenditures, made out in accordance with the form recommended by the United States Department of Agriculture, includes, first, the Government appropriation of $7,500, and, secondly, the annual appropriation of $1,800 made by the State of Connecticut, together with various supplemental receipts. These accounts have been duly audited according to law.

GOVERNMENT APPROPRIATION—RECEIPTS AND EXPENDITURES.

RECEIPTS.

United States Treasury,	$7,500 00

EXPENDITURES.

Salaries,	3,642 98
Labor,	1,006 03
Publications,	290 99
Postage and stationery,	262 21
Freight and express,	108 38
Heat, light, and water,	325 91
Chemical supplies,	190 05
Seeds, plants, and sundry supplies,	293 21
Feeding stuffs,	148 64
Tools, implements, and machinery,	7 27
Furniture and fixtures,	154 15
Scientific apparatus,	469 23
Live stock,	258 95
Traveling expenses,	205 01
Contingent expenses,	11 50
Building and repairs,	125 49
Total,	$7,500 00

STATE APPROPRIATION AND SUPPLEMENTAL RECEIPTS—RECEIPTS AND EXPENDITURES.

RECEIPTS.

State of Connecticut,	$1,800 00
Miscellaneous receipts:	
Gifts for special investigations,	300 00
Receipts from analyses,	100 00
Other receipts,	256 13
Total,	$2,456 13

EXPENDITURES.

Salaries,	$850 60
Labor,	456 40
Publications,	6 00
Postage and stationery,	22 83
Freight and express,	3 05
Heat light, and water,	15 19
Chemical supplies,	86 96
Bacteriological investigations and sundry supplies,	369 24
Furniture and fixtures,	10 65
Scientific apparatus,	635 21
Total,	$2,456 13

HENRY C. MILES, *Treasurer.*

Report of the Director for the Year 1897.

The present is the Tenth Annual Report of this Station. The operations of the Station actually began in the spring of 1888, so that the First Annual Report covered the work of only part of a year. The succeeding Reports have each included the work of a full year. By Act of the General Assembly of Connecticut the sum of $15,000, received annually by the State of Connecticut from the general Government for the purpose of maintaining an experiment station or stations, is divided, one-half being entrusted to the Board of Control of the State Experiment Station, and the other to the Board of Trustees of the Storrs Agricultural College. The Storrs Station thus has but $7,500 per annum from the general Government for its regular work. This sum has, however, during the past two years been supplemented by a grant of $1,800 per annum from the General Assembly of the State, to be used "for the purpose of investigating the economy of the food and nutrition of man, and for investigations of the bacteria of milk, butter, and cheese, and their effect in dairying." The whole income of the Station from public sources thus amounts to $9,300 per annum. Of the other stations in this and the neighboring States no one receives less than $15,000 per annum, while several have incomes of more than $25,000.

With so limited an income this Station would not be warranted in undertaking so numerous and extensive inquiries as those it has carried on, were it not for special advantages with which it has been, and still continues to be favored. Since its organization its chemical and bacteriological investigations have been carried on at Wesleyan University, whose laboratory and library facilities, with the services of experts, have been at its disposal. For a time the U. S. Department of Labor defrayed a part of the expense of dietary studies, accounts of which have been published in the Annual Reports of the Station. For several years past the Station has worked in coöperation with the U. S. Department of Agriculture in investigations of the

food and nutrition of man. The results of these inquiries have been published in part by the Department of Agriculture, and in part by the Station in its own Reports and Bulletins. These statements are appropriate in order to explain what might seem a disparity between the resources of the Station and the investigations it has undertaken.

The subjects of experimental investigation by the Station during the past year have been similar to those of previous years. This is in accordance with the policy of the Station since its foundation, namely, to undertake comparatively few lines of work, have these as nearly parallel as practicable, and continue them from year to year.

The principal inquiries have had to do with the nutrition of plants, animals, and man, and the bacteriology of the dairy. Meteorological observations have been made continuously. Besides the work of inquiry as such, no little attention has been given to the diffusion of the results obtained. To this end reports and bulletins are distributed in large numbers throughout the State of Connecticut and elsewhere. Facts are also given from time to time to the press for publication. The officers of the Station attend farmers' institutes and other meetings, and give lectures and addresses. Correspondence is carried on with persons interested in a large variety of subjects. And, finally, the Station is brought into the most direct connection with the practical farmers and dairymen of the State, by coöperative experiments conducted by these gentlemen on their own farms and in their own stables, with the aid of the Station and under its general direction.

Much of the experimental inquiry, it is true, is of an abstract scientific character, and its usefulness might not be apparent to the superficial observer. As a matter of fact, however, research of this character is of fundamental importance, and the fact that the Station has been able to undertake so much of it is, in the opinion of those best prepared to judge, one of the most fortunate circumstances connected with its organization and work.

THE WORK OF THE STATION DURING THE YEAR.

The several lines of inquiry followed and the objects, methods, and results of the work during the year may be briefly

outlined as follows. It should be stated, however, that not all of the work done is described in detail in the present report. In some instances the results are not yet ripe for publication, while in others the success of the experiments has been interfered with by untoward circumstances, and especially by unfavorable weather.

CORRESPONDENCE.

The correspondence of the Station is quite extensive. The letters written are very largely in answer to inquiries which come, not only from Connecticut, but from other parts of the United States, and from foreign countries. One reason for the extent of this correspondence is the fact that some of the subjects of investigation by the Station, especially those connected with the food and nutrition of man, are of very general interest, and that some of the methods and apparatus used are more or less novel. The extent of the correspondence, like the general work of the Station, is also increased through the relations with the Government investigations.

In this connection it may be added that the Director visited a considerable number of universities and experiment stations in several countries of Europe, including Russia, during the past summer, in order to become more familiar with certain methods and results of later investigation and experience. The information gained has proved decidedly helpful.

METEOROLOGICAL OBSERVATIONS.

These have been continued during the past year, as previously, at Storrs, where records have been made of temperature, barometric pressure, wind velocity, humidity, rainfall, and snowfall. In addition, records of rainfall during the growing season have been made in other places in the State by farmers who have coöperated with the Station.

FIELD EXPERIMENTS.

As in the previous years, the field experiments have occupied considerable attention. They have been mainly of two classes. The first class includes tests of the action of various fertilizers upon the growth and composition of the plants. The object of those of the second class has been to get light upon the fitness of certain forage crops for use in Connecticut, and

the experiments themselves have had to do with the growth of these crops, their composition and their digestibility, and nutritive value. Especial attention has been given to the legumes.

For a number of years the Station was at pains to introduce soil tests with fertilizers on farms in different parts of the State. The plan of these experiments consisted in dividing a field into parallel strips and applying different fertilizers to the strips of land, repeating the same materials on the same plots year after year, but rotating the crops. The especial purpose has been to learn the needs of the soils and crops and the best ways of supplying them by fertilizers. Similar soil-test experiments have been carried on at the Station since its foundation. The coöperative soil tests carried out by private individuals have proven very useful, but have, in the course of years, naturally given place to other inquiries.

Experiments on the effects of nitrogenous fertilizers upon the yield and composition of various crops, including grasses, corn, and legumes, have been conducted at the Station for several years past. The results of these experiments have been published in the Annual Reports and Bulletins of the Station. Owing to excessive rains in July and August, 1897, which seriously reduced the yields and caused some irregularities in the experiments upon the effects of nitrogenous fertilizers upon corn and upon certain legumes, the results for the past year are not reported. It is hoped that the results of the experiments of several years on the influence of nitrogenous fertilizers upon the nitrogen in different crops may be summarized in a report of the Station at no distant date. Meanwhile it may be said that these indicate more and more clearly the advantage of nitrogen in fertilizers for grasses and cereals, and the poor economy in their use for legumes. They bring out, especially, one important factor which has hitherto been generally overlooked. It is that the effect of nitrogenous fertilizers upon grasses and cereals is not simply to increase the yield, but also to increase the percentage of protein, and hence to improve the feeding value. This two-fold advantage of nitrogenous fertilizers is a matter which is well worthy of the consideration of farmers in Connecticut, especially in view of the advantage of nitrogenous materials as fodder for stock, which is shown by late experiments at this Station as well as elsewhere.

BACTERIOLOGY OF DAIRY PRODUCTS.

The work upon the bacteria of milk and butter has been continued during the year by Professor Conn and his assistant, Mr. Esten. The important subject of cream ripening continues to occupy attention. The especial object of the experimental work of the last two years has been to get light upon the kinds of bacteria that are common in Connecticut dairies, their sources, and the influence that they exert upon butter when they get into the cream and grow during the ripening process. At the same time a large number of special studies of individual species of bacteria are being carried out by the ordinary experimental methods. With the rest, the study of *Bacillus acidi lactici* has been continued by Mr. Esten. A part of the experimental work, however, has been temporarily interrupted during the year by the absence of Prof. Conn, who is spending the year in Europe. He is not only giving especial attention to bacteriological studies in university laboratories, but is also visiting a number of countries where dairying is particularly well developed, and is improving the opportunity there offered for learning the results of the latest investigation and experience regarding the action of bacteria in milk, butter, and cheese, and also regarding the important question of tuberculosis in milk. With the rest he has visited large establishments in Holland, Germany, Denmark, and Sweden, and has seen the workings of a number of leading creameries and dairies, and studied the methods in actual operation. He has naturally devoted careful attention to the methods for prevention of tuberculosis in cattle, and of securing milk free from tuberculous organisms. In so doing he has examined establishments where milk is pasteurized, so as to furnish it to consumers free from danger of distributing disease. The fact that no details regarding investigations upon dairy bacteriology and kindred subjects are contained in the present Report is explained in part by the large amount of other material which demanded publication and in part by the absence of Prof. Conn. It is hoped, however, that a succeeding report may contain much interesting matter upon this subject.

TUBERCULOSIS.

Four cows, condemned by the State Commission on Diseases of Domestic Animals in the fall of 1896, were at that time

placed at the disposal of the Station. These cows have been held in quarantine and used for certain experiments on the effects of the milk of diseased cows when fed to calves, and, incidentally, to study the efficiency of the tuberculin test as a diagnostic agent in the detection of tuberculosis. One reason for choosing these particular animals was that the disease was supposed to be in its earlier stages at the time they were brought to the Station. Thus far the experiments imply that healthy calves may be reared on the milk of tuberculous cows where the disease has not attacked the udder. The results from the use of tuberculin seem to indicate that its efficiency as a diagnostic agent is not as great as has sometimes been claimed. Why animals respond at one time to the test and do not respond at another we cannot even conjecture safely. We can, however, say that much remains to be learned regarding the tuberculin test and its value, and regarding the dangers to our herds and to human lives from tuberculosis.

FEEDING EXPERIMENTS WITH DOMESTIC ANIMALS.

These have included during the past year digestion experiments with sheep and experiments on the effect of fodder upon milk production by dairy herds.

Digestion Experiments with Sheep.—These have been made during the past, as in previous years, on certain forage crops, grain feeds, and concentrated by-products. They not only have a value for increasing the general fund of information regarding the digestibility of feeding stuffs, but are of direct use in connection with the feeding experiments with milch cows. It has been found by comparative experiments that the digestibility of the same kind of feeding stuffs is very nearly the same with cows as with sheep. Hence the results of digestion experiments with sheep may be taken as measuring the digestibility of different feeds by cattle. The greater ease with which sheep can be handled in digestion experiments is the principal reason for using them instead of cows.

Feeding Experiments with Dairy Herds.—The importance of dairying as a branch of agriculture in this State has led to considerable study of the effects of feeding upon the milk production of cows. In previous years a part of the work of the Station in this line has been carried out in its own stables, especial

attention being given to the feeding value of forage crops. At the same time more or less extended observations have been made of the actual feeding practice of intelligent dairymen in different parts of the State. In carrying out these observations a representative of the Station has spent several days at each place, and has made weighings of the feed and of the milk determining the amount of butter-fat in the milk of each cow and taking samples of each feeding stuff for analysis by the Station. In a number of cases when such observations have been carried on for a certain period, the Station has made suggestions as to advisable changes in the feeding, and after the changes have been made the effect upon the milk production has been observed by a second period of observations similar to the first. During the past five years some 45 tests have been made with 453 cows in 32 herds in different parts of the State. The college herd at Storrs is now available for experimental purposes, and series of experiments are in progress there as in other places in the State. The main object of these experiments has been to find how farmers in the State are feeding, and, by comparing their methods with the teachings of experiments elsewhere, to make suggestions for improvement. At the same time the management of the experiments has been such as to bring new and valuable information regarding the economy of the feeding of cows for the production of milk and butter. The experiments of the past year, like those of previous years, point quite clearly to the value of rations with large proportions of protein for milk production.

A summary of the work done in this line by the Station up to the present time, together with reference to the results of similar inquiries elsewhere, forms the subject of the first two articles of the present Report.

EXPERIMENTS WITH THE RESPIRATION CALORIMETER.

Experiments of the kind above reported do not bring the exact information that the farmer needs for the most economical feeding of his stock, for the reason that they do not reveal the underlying laws of animal nutrition. To discover these experimenting of a more detailed and abstract nature is required. During the past thirty years or more the advance of knowledge regarding the nutritive values of feeding stuffs and

the most economical methods of feeding cattle, horses, sheep, swine, and other animals according as growth, fattening, milk, or work is demanded, has been very rapid. Only those who are familiar with the subject realize how large an amount of experimenting has been done during this time in Europe, and, of late, in the United States. Nor can any intelligent student of the subject doubt for a moment that the results are worth many times the cost, great as the latter has been. We are now coming to a time when the common ways of experimenting do not suffice to meet the demands of either the physiologist or the farmer for more accurate knowledge. It is becoming necessary to provide for experiments which shall show with the greatest possible accuracy just how food is used in the animal body, and what are the specific effects, not only of different food materials, but especially of the different nutritive ingredients in the nourishment of animals of different kinds and under different conditions. The most useful inquiry in this direction has been carried out with a so-called respiration apparatus, of which numerous forms have been used in experiment stations and university laboratories in Europe. This is an apparatus by the use of which the chemical elements and compounds of the income and outgo of the body are carefully measured. For the most satisfactory results still further measurements of the amounts of energy received by the body in the latent force of food and given off by the body as heat, external muscular work, or otherwise, are needed. An apparatus for the study of the metabolism of both matter and energy has been in the process of development for several years at Wesleyan University with the coöperation of the Station, and, lately, with that of the United States Department of Agriculture. The results obtained have more than fulfilled the expectations at the outset. The actual experiments thus far have been made with men, but plans are under consideration for extending the inquiries so as to include experiments with domestic animals.

FOOD AND NUTRITION OF MAN.

As there is room for the improvement in the economy of feeding of farm animals so there is even more demand for improvement in the food and nutrition of men, women, and children. By as much as man is of more importance than the

beast that serves him, by so much is it of more consequence that the relation his food bears to his health, strength, and purse should be understood. The experiment stations of the country have been studying the feeding of the plant and the animal. They are now turning their attention to the food and nutrition of man. An inquiry into the economy of the food of the people of the United States has been going on for some years, by the aid of an appropriation from Congress, and under the direction and authority of the Department of Agriculture. This inquiry is being carried out in coöperation with the experiment stations and other institutions in different parts of the country from Maine to California, and from Minnesota to Alabama. The immediate charge of these investigations has been given to the Director of the Storrs Station. The Legislature of Connecticut has wisely given to the Station a supplementary appropriation for this purpose. The details of so much of this work as is being carried out in Connecticut are published from time to time in the Reports and Bulletins of the Station.

Dietary Studies.—By means of dietary studies we are enabled to learn the quantities of nutrients consumed daily by people of different occupation, and of different age and sex. These studies bring out, also, the peculiar dietary usage of different families, their methods of purchase and preparation of foods, the amount wasted, and the ways in which improvements could be made to the advantage of both health and purse.

One result of these studies is to indicate that our diet, like the food we are feeding to our animals, is one-sided; that it lacks protein; and, furthermore, the same policy by which the farmer increases the nitrogen of his crops and of the fodder for his stock will increase the protein in the food which he produces for the support of the community. Thus science and practice are working together harmoniously, not only to improve the nourishment of the plant and the animal, but, what is incomparably more important, to improve the food and nutrition of man.

Digestion Experiments.—We have to-day a reasonably fair idea of the chemical composition of the food materials most commonly used in the United States. Their nutritive value, however, depends upon not only the proportions of the different

nutrients — protein, fats, carbohydrates, etc. — but also upon the amounts of those nutrients which can be actually digested and used by the body for its nourishment. The Station is conducting a series of experiments upon the digestibility and nutritive value of ordinary food materials in order to get light upon this latter factor—that of the nutritive value.

A considerable number of such experiments have been made in Europe, and recently this line of investigation has been taken up to a considerable extent in this country. In the Report of this Station for 1896 twelve digestion experiments were given in detail, and several more are included in the present Report.

Fuel Values of Foods and Feeding Stuffs.—Another factor of the value of food for nourishment is what may be called the fuel value, *i. e.*, the amount of potential energy in the food which the body can transform into heat, muscular power, or other forms of energy needed for its use. An apparatus employed for the study of this subject, and known as the bomb calorimeter, has been developed, and accounts of its use have appeared in the Reports of the Station.

STUDIES OF CHEMICAL METHODS.

In connection with the routine chemical work called for in the analyses of foods and feeding stuffs, in digestion experiments, and in the experimental research with the respiration calorimeter, considerable attention has been given to the study of the methods of chemical and physical inquiry involved. Such of the results as are of general scientific interest will, it is expected, be published in due time.

INDEX.

Besides the index which accompanies each Annual Report an index of the first five volumes was appended to the fifth volume. In like manner an index of the first ten volumes is planned for the present volume.

W. O. ATWATER,
Director.

A STUDY OF RATIONS FED TO MILCH COWS IN CONNECTICUT.

See [illegible] 13

REPORTED BY W. O. ATWATER AND C. S. PHELPS.

Dairying is a very important industry in Connecticut. According to the statistics of the census of 1890* in only two States, New York and Iowa, are there more cows per square mile. The milk product of our herds, when valued at 2½ cents per quart, is equal to nearly five and one-half millions of dollars, while the butter, estimated at 20 cents per pound, would have a value of over two millions of dollars. Investigations of dairy problems constitute an important part of the work of the Station. Much of this work has been of a coöperative nature; the experiments being carried out upon the farms of some of our more progressive dairymen. The interest taken in this work by our dairymen in general has been very encouraging, and the inquiries for information received by the Station regarding feeding and other dairy matters are increasing year by year.

The study of rations fed to milch cows on dairy farms in this State, which was begun in the winter of 1892–93, has been repeated each winter since. Detailed descriptions of the work of the first four winters have been given in the Station publications.† The results of the fifth winter's work (1896–97) are here reported.

Each herd was selected after a personal inspection, or after sufficient correspondence to satisfy ourselves of its fitness for the proposed tests, and a representative of the Station was present during the whole period of each test and personally attended to the details of the experiment, such as weighing the feeding stuffs, and taking samples for analyses, and weighing, sampling and determining the butter-fat in the milk. This work was faithfully performed by Mr. E. B. Fitts, Assistant in Farm Experiments at the Station.

* See especially U. S. Department of Agriculture, Bureau of Animal Industry Bulletin No. 11, on Statistics of the Dairy.

† Reports of this Station for 1893, pp. 69–115; 1894, pp. 26–56; 1895, pp. 40–76; and 1896, pp. 41–76. Bulletin 13 of this Station. Reports of the Connecticut Board of Agriculture, 1893, pp. 182–199; and 1894, pp. 131–146.

In the first winter's work (1892–93), which was regarded as preliminary to an investigation that might extend over a series of years, it was thought better to examine a relatively large number of herds, each during a short period, than to make the periods longer and the number of herds less. Sixteen herds were visited and a five-days' test was made of each.

In the second winter's work (1893–94) six different herds were visited, and in four cases the time of study of the feeding and milk of each herd was extended to twelve days. The analyses of the feeding stuffs were made at once, and the weights of nutrients in the rations as fed were calculated. In three instances other rations were thereupon suggested by the Station as being better than the ones that had been used. The owners gradually changed the food to the ration thus proposed, and after an interval of four weeks from the close of the first test, another twelve-days' test was made of the same herd. A comparison was thus made of the yields of milk and butter-fat with the two different rations.

During the third winter (1894–95) four herds were visited, each herd being under observation for twelve days at two different periods in the same manner as the three herds studied in 1893–94, except that there was only a two-weeks' interval between the two tests on the same herd. During the interval between the tests the feeding stuffs were analyzed as in the preceding test and the ration for the second period modified in accordance.

During the fourth winter (1895–96) two herds were studied in a similar way, except that only nine days elapsed between the two tests, and the change from one ration to the other was made under the supervision of the person in charge of the experiment. In one case, the first ration had a much larger proportion of protein than we have commonly found in use on dairy farms in this State. In both cases the quantity and proportion of protein was increased in the second ration. Samples of the different feeding stuffs used in the tests were taken early in each test and sent to the laboratory for analysis.

The work of the fifth winter (1896–97) included studies of four herds according to the methods of the two previous years. Two weeks were allowed for changing the feeds between the

two tests on the same herd. In the rations fed to one of the herds the nutritive ratio in the first test was as narrow as in the standard tentatively suggested by the Station, but in this case as in the others the second ration was made still narrower.

CALCULATION OF RATIONS USED.

In the experiments of 1893–94 and 1894–95, as soon as it was possible to obtain the results of the analyses of the feeds used in the first test, the proportions of nutrients in the ration were calculated, and suggestions were made for changes in the ration. After changes had been made and the animals had been upon the new ration for two weeks or longer, the herd was again visited and a new twelve-days' test was made. In the tests during 1895–96, as the interval of nine days between the two tests on the same herd was insufficient for the analyses, it became necessary to calculate the first ration from tables of average analyses, as a basis for formulating a new ration. This was done with the idea that it would be best to have the Station make the change of feed. The time proved rather short, however, for making the change, and during the winter of 1896–97 we returned to the plan of allowing two weeks between tests on the same herd. In this work also the rations used in the first test were calculated from tables of average composition before change of feed was made. The analyses were made, however, in all cases.

OBJECT OF THE EXPERIMENTS, AND THE CHIEF POINTS OF INFORMATION OBTAINED.

The main object in all of these experiments has been to ascertain what kinds of rations the dairymen were actually feeding; to study the effect of these rations upon the yields of milk and butter-fat; and, in cases where it was thought that the rations were not as advantageous as might be fed, to make suggestions for improvement, and to study the effects of the new rations on the milk product. In the first winter's work (1892–93) all of the rations reported were those found in actual use by practical feeders, and in the later work where two tests were made on the same herd the first ration in all cases was the one in actual use by the dairyman whose herd was studied, while the ration used in the second test was suggested by the Station.

The chief points upon which information was obtained were:

Number of animals in the herd.—In considering the number of animals, only those which came into the test were included. Usually these were all of the cows on the farm which were giving a fair quantity of milk at the time of the test, except those which were nearly dry and a few which were "off feed" for some reason.

Breed, age, and approximate weight of each cow.—The breed and age were obtained as accurately as possible from the owner. Since it was not practicable to take to the farm scales large enough on which to weigh the cows, the weights were estimated. This estimate was made in each case by the Station representative or the owner, and it is thought that the errors of judgment were not large.

Number of months since last calf.—In most cases the time at which the cow dropped her last calf was known.

Number of months till due to calve.—There was, of course, more or less uncertainty in this regard.

Weights of milk-flow for the full number of days of the test.—The milk of each cow at each milking was weighed as soon as milked, to the nearest tenth of a pound, by the Station representative.

Percentages and amounts of butter-fat in the milk.—A sample of the milk of each cow, night and morning, was taken, and from the combined sample a determination of the quantity of butter-fat was made. The Babcock method of fat determination was employed. From the percentages of butter-fat in the milk, and the total weights of the milk, the daily yields of butter-fat were obtained.

Kinds and weights of foods used.—The feeder was requested to use the same kinds and amounts of feeding stuffs during the first test as he had previously been using. The quantity for each animal was weighed by the Station representative just before feeding. Any portions of the food left uneaten by the cows were weighed, and due allowance was made for these uneaten residues in estimating the amounts daily eaten. During the early part of the test, samples of each feeding stuff used were carefully taken and at once sent to the laboratory for analysis. From the results of the analyses and the weights fed, the total nutrients (protein, fat, nitrogen-free extract, and

fiber) fed each day were calculated. By the use of digestion coefficients, estimates were made of the weights of digestible nutrients in each day's ration.*

RESULTS OF EXPERIMENTS DURING THE WINTER OF 1896–97.

Tables 1 to 8 inclusive contain the results of the observations and studies of the different herds.

The following abbreviations are used in the tables:

G.=Grade.	P.=Pure-bred.	Gy.=Guernsey.
R.=Registered.	Jy.=Jersey.	Hol.=Holstein.

Each of the following tables gives the condensed results of a single test. The tables are alike in arrangement, except in a few cases in which there were irregularities in the feeding, and to which attention is called in the proper place. An explanation of one therefore will do for all.

Each table is in two parts. The upper part gives the statistics of the herd, the average daily milk flow, the percentage of fat in each day's milk, and the yields of butter-fat, for each cow used in the test. This portion of the table follows the same plan in all cases, and requires no explanation.

The lower part of each table gives the kinds and amounts of the different feeding stuffs eaten per day, and the weights of the digestible nutrients (protein, fat, and carbohydrates) which they were estimated to furnish. The weights of foods and nutrients are calculated per 1,000 pounds live weight and also "per average weight" of each herd. The figures for average weight, which are given at the right of the table, represent the average amount actually fed per animal per day.

All of the feeding stuffs used in these rations were analyzed. The analyses are given in the article on Analyses of Fodders and Feeding Stuffs beyond. From the weights of the different feeding stuffs, the results of the analyses, and the digestion coefficients given in the following table, the weights of digestible nutrients were calculated in the usual way. The fuel values of the different foods were obtained by multiplying the number of pounds of digestible protein and carbohydrates by 1860, and the number of pounds of digestible fat by 4220, and taking the sum of these products as the number of calories of energy in the materials available for the use of the animal.

* For explanations of technical terms, see article on Nitrogenous Feeding Stuffs beyond.

Only a part of each of the various nutrients contained in any feeding stuff is digested by the animal. For our purpose, therefore, it does not suffice to know the kinds, amounts, and chemical composition of the feeding stuffs which the animal eats. We must also know the quantities of protein, fat, and carbohydrates that actually become available for use. The proportions of the different nutrients that can be digested depend upon the digestive powers of the animal and the character of the feeding stuff. The average proportions of each ingredient of any feeding stuff which are found by experiment to be actually digested are commonly expressed in percentages, and in that form are designated as coefficients of digestibility.[1]

Coefficients of digestibility employed in calculating the digestible nutrients in the different feeding stuffs used in these rations.[2]

Kinds of Feeding Stuffs.	Protein.	Fat.	Carbohydrates.	
			Nitrogen-free Extract.	Fiber.
	%	%	%	%
Chicago gluten meal,	87*	88*	91*	33†
Rockford gluten feed,	87*	88*	91*	33†
Buffalo gluten feed,	87*	88*	91*	33†
Cotton seed meal,	89*	100*	68*	33†
O. P. linseed meal,	86†	90†	80†	50†
Rye meal,	84*	64*	92*	33†
Corn and cob meal,	76*	82*	84*	28*
Wheat bran,	78*	76*	72*	33†
Wheat middlings,	79*	85*	83*	33†
Fine wheat feed,	79*	85*	83*	33*
Corn meal,	76†	92†	87†	58†
Ground oats,	78†	84†	77†	26†
Corn ensilage,	46*	80*	67*	67*
Corn stover,	52*	52*	64*	66*
Potatoes,	44*	13*	91*	—
Turnips,	84*	77*	95*	80*
Hay (mixed grasses),	54*	54*	63*	55*
Bog hay,	45*	28*	60*	46*
Oat hay,	53*	61*	52*	43*
Oat straw,	53*	61*	52*	43*

* From results of American digestion experiments.

† From results of German digestion experiments.

[1] For explanation of this subject, see articles on digestion experiments, and especially those on the digestibility of feeding stuffs and the calculation of rations in the Report of this Station for 1893, pages 156 and 168.

[2] New tables of average coefficients of digestibility have been published since this series of experiments was started in 1892, but the changes are slight, and in order to have the rations comparable, the original factors have been retained throughout. The later results are referred to in the article on Nitrogenous Feeding Stuffs beyond.

The coefficients of digestibility used here are given in the preceding table. They are based upon the results of digestion experiments with domestic animals. Where such experiments have been made in this country, in sufficient number to give reliable results, these are used for these coefficients. In other cases the results of European (and especially German) experiments have been drawn upon for the purpose.

DETAILS OF THE STUDIES OF THE WINTER OF 1896–97 (FIFTH SEASON).

Studies of four herds were made during the past year (1896–97). The results of these are given on pages 24–34.

As in previous reports the herds are designated by the letters of the alphabet and the tests by numbers. Those for this season are: Herd J, tests Nos. 39 and 41; Herd K, tests Nos. 40 and 42; Herd L, tests Nos. 43 and 45; Herd M, tests Nos. 44 and 46.

The names and residences of the owners are given in table 9 beyond.

The studies of the first herd are designated as tests No. 39 and No. 41, pages 24 and 25. The first test began December 14, 1896, and continued twelve days. The cows were watered once a day from a well. The hay used was from mixed grasses grown on low meadow land. The oat hay was cut when the grain was in the milk. The corn ensilage was from whole corn cut when the ears had begun to glaze. The grain was a mixture of four parts corn meal with five parts Buffalo gluten feed. The second test with this herd (No. 41) began January 11, 1897, about a fortnight after the close of the first test, and continued twelve days. The same kinds of coarse fodders were fed as in the first test, but the grain feed was made up of four parts Buffalo gluten feed, three parts wheat bran, and two parts cottonseed meal. Thirteen cows were included in these tests. They were all in good condition, and no irregularities occurred in the experiment.

TABLE I.

Dairy Test No. 39.—Statistics of Herd J from December 14, 1896, to December 26, 1896.

Ref. No.	Breed.	Age.	Weight.	Mos. since Last Calf.	Daily Milk Flow.			Daily Percentage of Fat.			Daily Yield of Fat.		
					Min.	Max.	Avg.	Min.	Max.	Avg.	Min.	Max.	Avg.
		Yrs.	Lbs.	Mos.	Lbs.	Lbs.	Lbs.	%	%	%	Lbs.	Lbs.	Lbs.
1	G. Jy., - -	2	600	3	14.1	15.1	**14.6**	4.0	4.5	**4.2**	.56	.67	**.61**
2	G. Jy., - -	3	675	3	21.0	22.9	**21.9**	3.5	4.4	**4.0**	.75	.96	**.87**
3	G. Jy., - -	6	725	5	10.7	12.1	**11.3**	5.1	5.5	**5.3**	.57	.65	**.60**
4	G. Jy., - -	11	800	9	15.9	18.9	**17.6**	4.1	5.1	**4.5**	.66	.89	**.79**
5	G. Jy., - -	7	775	9	14.9	18.2	**16.5**	4.4	5.0	**4.7**	.66	.85	**.77**
6	G. Jy., - -	11	775	3	5.3	6.5	**5.6**	4.8	5.6	**5.4**	.27	.36	**.30**
7	G. Jy., - -	10	750	2	19.9	22.9	**21.3**	4.0	5.1	**4.5**	.85	1.03	**.96**
8	G. Jy., - -	10	750	10	10.9	13.0	**12.3**	3.9	5.3	**4.2**	.47	.58	**.51**
9	G. Jy., - -	4	675	4	22.2	24.6	**23.4**	3.8	5.1	**4.7**	.77	1.20	**1.08**
10	Jy. and Gy.,	6	750	6	19.4	21.3	**20.3**	2.6	4.2	**3.5**	.49	.91	**.70**
11	G. Jy., - -	2	725	2	15.5	17.9	**16.7**	3.3	4.3	**4.0**	.56	.73	**.66**
12	G. Jy., - -	4	750	4	15.1	18.2	**16.9**	4.3	5.3	**4.8**	.70	.91	**.82**
13	G. Jy., - -	5	625	5	22.2	24.6	**23.9**	3.8	4.4	**4.1**	.89	1.06	**.98**
	Herd avg., -	—	**725**	—	—	—	**17.1**	—	—	**4.5**	—	—	**.74**

Pounds of food and nutrients per day per 1000 pounds, live weight, and per average weight (725 pounds) of herd.

Kinds of Food.	Per 1000 Lbs., Live Weight.						Per Average Weight (725 Lbs.) of Herd.				
	Average Fed per Day.	Digestible Nutrients and Fuel Value.					Average Fed per Day.	Digestible Nutrients and Fuel Value.			
		Protein.	Fat.	Carbohydrates.	Nutritive Ratio.	Fuel Value.		Protein.	Fat.	Carbohydrates.	Fuel Value.
	Lbs.	Lbs.	Lbs	Lbs.	1:	Cal.	Lbs.	Lbs.	Lbs	Lbs.	Cal.
Average per Day.											
Grain mixture,* -	10.0	1.53	.32	5.44	4.0	14300	7.3	1.11	.23	3.94	10350
Corn ensilage, -	39.2	.41	.33	6.35	—	—	28.4	.29	.24	4.60	—
Oat hay, - -	8.7	.31	.12	3.19	—	—	6.3	.22	.08	2.31	—
Hay, - - -	4.7	.16	.04	1.82	—	—	3.4	.12	.03	1.32	—
Potatoes, - -	11.5	.09	–	1.49	—	—	8.3	.07	–	1.08	—
Total coarse food,	64.1	.97	.49	12.85	14.4	27750	46.4	.70	.35	9.31	20100
Total food, -	**74.1**	**2.50**	**.81**	**18.29**	**8.0**	**42050**	**53.7**	**1.81**	**.58**	**13.25**	**30450**
Minimum per Day.											
Concentrated food,	9.9	1.51	.31	5.37	4.0	14100	7.2	1.09	.23	3.89	10250
Coarse food, - -	57.9	.89	.43	11.59	14.2	25050	42.0	.65	.31	8.40	18100
Total food, -	67.8	2.40	.74	16.96	7.1	39150	49.2	1.74	.54	12.29	28350
Maximum per Day.											
Concentrated food,	10.5	1.60	.32	5.70	4.0	14900	7.6	1.15	.23	4.13	10800
Coarse food, - -	72.8	1.13	.55	14.79	14.2	31900	52.8	.81	.40	10.72	23150
Total food, -	83.3	2.70	.87	20.49	8.3	46800	60.4	1.96	.63	14.85	33950

* The grain used was mixed as follows: Corn meal, 3.2 lbs.; Buffalo gluten feed, 4.1 lbs. Total, 7.3 lbs. per day per average weight of herd.

TABLE 2.

Dairy Test No. 41.—Statistics of Herd J from January 11, 1897, to January 23, 1897.

Ref. No.	Breed.	Age.	Weight.	Mos. since Last Calf.	Daily Milk Flow. Min.	Max.	Avg.	Daily Percentage of Fat. Min.	Max.	Avg.	Daily Yield of Fat. Min.	Max.	Avg.
		Yrs.	Lbs.	Mos.	Lbs.	Lbs.	Lbs.	%	%	%	Lbs.	Lbs.	Lbs.
1	G. Jy., - -	2	600	4	13.3	15.2	14.6	4.3	4.7	4.5	.60	.68	.66
2	G. Jy., - -	3	675	4	19.6	22.9	21.8	4.1	4.5	4.3	.84	1.03	.93
3	G. Jy., - -	6	725	6	10.2	12.8	11.8	5.1	5.9	5.4	.58	.67	.63
4	G. Jy., - -	11	800	10	16.2	18.9	17.8	4.5	5.0	4.7	.77	.89	.84
5	G. Jy., - -	7	775	10	14.6	16.8	15.9	4.8	5.4	5.1	.72	.88	.81
6	G. Jy., - -	11	775	4	5.9	6.2	5.5	5.6	5.9	5.3	.34	.36	.32
7	G. Jy., - -	10	750	3	19.1	20.8	20.1	4.5	5.1	4.9	.93	1.03	.98
8	G. Jy., - -	10	750	11	11.2	12.9	12.1	3.9	4.3	4.2	.47	.53	.50
9	G. Jy., - -	4	675	5	20.8	23.9	21.8	5.0	5.8	5.5	1.07	1.36	1.19
10	Jy. and Gy.,	6	750	7	16.6	18.9	18.1	3.9	4.1	4.0	.65	.76	.72
11	G. Jy., - -	2	725	3	14.8	16.9	15.9	3.9	4.4	4.1	.59	.73	.66
12	G. Jy., - -	4	750	5	14.2	17.6	16.1	4.7	5.6	5.2	.70	.99	.84
13	G. Jy., - -	5	625	6	22.6	24.6	23.9	4.3	4.9	4.5	1.03	1.15	1.07
	Herd avg., -	—	725	—	—	—	16.6	—	—	4.8	—	—	.78

Pounds of food and nutrients per day per 1000 pounds, live weight, and per average weight (725 lbs.) of herd.

Kinds of Food.	Per 1000 Lbs., Live Weight. Average Fed per Day.	Digestible Nutrients and Fuel Value. Protein.	Fat.	Carbohydrates.	Nutritive Ratio.	Fuel Value.	Per Average Weight (725 Lbs.) of Herd. Average Fed per Day.	Digestible Nutrients and Fuel Value. Protein.	Fat.	Carbohydrates.	Fuel Value.
Average per Day.	Lbs.	Lbs.	Lbs.	Lbs.	1:	Cal.	Lbs.	Lbs.	Lbs	Lbs.	Cal.
Grain mixture,* -	11.3	2.55	.53	4.03	2.1	14500	8.2	1.85	.38	2.92	10500
Corn ensilage, -	39.2	.47	.34	7.11	—	—	28.4	.34	.25	5.15	—
Oat hay, - -	5.6	.19	.08	2.03	—	—	4.1	.14	.06	1.47	—
Hay, - - -	3.9	.16	.06	1.67	—	—	2.8	.11	.04	1.21	—
Total coarse food,	48.7	.82	.48	10.81	14.5	23650	35.3	.59	.35	7.83	17100
Total food, -	**60.0**	**3.37**	**1.01**	**14.84**	**5.1**	**38150**	**43.5**	**2.44**	**.73**	**10.75**	**27600**
Minimum per Day.											
Concentrated food,	10.7	2.45	.51	3.89	2.1	13950	7.8	1.78	.37	2.82	10100
Coarse food, -	47.3	.77	.46	10.32	7.7	22550	34.3	.56	.33	7.48	16350
Total food, -	58.0	3.22	.97	14.21	5.1	36500	42.1	2.34	.70	10.30	26450
Maximum per Day.											
Concentrated food,	11.1	2.55	.53	4.02	2.2	14450	8.0	1.85	.39	2.91	10500
Coarse food, -	49.8	.85	.50	11.27	14.6	24650	36.1	.62	.36	8.17	17850
Total food, -	60.9	3.40	1.03	15.29	5.3	39100	44.1	2.47	.75	11.08	28350

* The grain used was mixed as follows: Buffalo gluten feed, 3.7 lbs.; wheat bran, 2.7 lbs.; cotton seed meal, 1.8 lbs. Total, 8.2 lbs. per day per average weight of herd.

The studies of the second herd included tests No. 40 and No. 42. The first test began December 28, 1896, and continued twelve days. The cows were watered from a trough in the manger, but were let out each day for exercise. The grain feed was a mixture of eighty parts corn meal, thirty parts wheat bran, five parts ground oats, and three parts ground rye. Cottonseed meal was fed in addition to the grain mixture. The corn stover was cut into inch lengths, and was practically all eaten. The same amount of grain feed was not fed each cow. Hence it is necessary in the tables to divide the herd into two groups. One group, composed of cows Nos. 3, 4, 5, 6, and 7, was fed the grain mixture but once a day, in the morning; the other group, cows Nos. 1, 2, 8, and 9, received the grain feed twice a day, thus receiving double the amount fed the first group.

The second test with this herd began January 25, 1897, about two weeks after the close of the first test, and continued the usual period of twelve days. Cottonseed meal was fed as before, but the grain mixture was changed to three parts of wheat bran, ten of corn meal, and ten of Chicago gluten feed.

Just previous to and during the period of the second test a malady, which caused a looseness of the bowels, affected a part of the herd. For this reason it was necessary to exclude six cows from the tests.

TABLE 3.

Dairy Test No. 40.—Statistics of Herd K from December 28, 1896, to January 9, 1897.

Ref. No.	Breed.	Age.	Weight.	Mos. since Last Calf.	Daily Milk Flow.			Daily Percentage of Fat.			Daily Yield of Fat.		
					Min.	Max.	Avg.	Min.	Max.	Avg.	Min.	Max.	Avg.
		Yrs.	Lbs.	Mos.	Lbs.	Lbs.	Lbs.	%	%	%	Lbs.	Lbs.	Lbs.
3	R. Jy., - -	8	725	4	11.3	13.6	**12.5**	5.9	6.5	**6.1**	.68	.83	**.76**
4	G. Jy., - -	12	800	50	13.0	14.4	**13.5**	5.6	6.3	**5.9**	.73	.86	**.80**
5	G. Jy., - -	9	750	2	14.7	17.0	**15.9**	5.0	5.5	**5.2**	.76	.91	**.83**
6	G. Jy., - -	7	725	4	15.9	18.6	**17.3**	4.4	5.0	**4.7**	.76	.90	**.82**
7	R. Jy., - -	7	650	4	15.5	18.0	**16.4**	4.8	5.3	**5.1**	.73	.86	**.83**
	Avg., -	—	**725**	—	—	—	**15.1**	—	—	**5.4**	—	—	**.81**
1	G. Jy., - -	12	800	4	16.4	18.9	**17.7**	4.3	4.8	**4.5**	.72	.87	**.80**
2	G. Jy., - -	12	800	2	19.0	24.7	**23.3**	4.4	5.5	**4.8**	.93	1.36	**1.13**
8	G. Jy., - -	5	675	1	20.2	23.3	**21.7**	4.9	5.4	**5.1**	1.04	1.17	**1.12**
9	G. Jy., - -	2	750	2	12.4	14.9	**13.7**	5.1	5.8	**5.5**	.69	.83	**.75**
	Avg., -	—	**750**	—	—	—	**19.1**	—	—	**5.0**	—	—	**.95**
	Herd avg., -	—	**750**	—	—	—	**16.9**	—	—	**5.2**	—	—	**.87**

TABLE 3.—*(Continued.)*

Pounds of food and nutrients per day per 1000 pounds, live weight, and per average weight (750 pounds) of herd.

Kinds of Food.	Per 1000 Lbs., Live Weight.						Per Average Weight (750 Lbs.) of Herd.				
	Average Fed per Day.	Digestible Nutrients and Fuel Value.					Average Fed per Day.	Digestible Nutrients and Fuel Value.			
		Protein.	Fat.	Carbo-hydrates.	Nutritive Ratio.	Fuel Value.		Protein.	Fat.	Carbo-hydrates.	Fuel Value.
Cows 3, 4, 5, 6, 7. *Avg. Wt., 725 Lbs. Average per Day.*	Lbs.	Lbs.	Lbs.	Lbs.	1:	Cal.	Lbs.	Lbs.	Lbs	Lbs.	Cal.
Grain mixture,* -	4.3	.32	.15	2.49	—	—	3.1	.23	.11	1.81	—
Cotton seed meal,	2.7	1.16	.41	.40	—	—	2.0	.84	.30	.29	—
Total conc. food,	7.0	1.48	.56	2.89	2.8	10500	5.1	1.07	.41	2.10	7650
Corn ensilage, -	39.0	.43	.31	6.15	—	—	28.3	.31	.23	4.46	—
Corn stover, -	8.9	.19	.10	4.48	—	—	6.4	.14	.07	3.25	—
Hay, - - -	5.8	.22	.10	2.69	—	—	4.2	.16	.07	1.95	—
Total coarse food,	53.7	.84	.51	13.32	17.3	28500	38.9	.61	.37	9.66	20650
Total food, -	**60.7**	**2.32**	**1.07**	**16.21**	**8.0**	**39000**	**44.0**	**1.68**	**.78**	**11.76**	**28300**
Cows 1, 2, 8, 9. *Avg. Wt., 750 Lbs. Average per Day.*											
Grain mixture,* -	8.2	.59	.29	4.75	—	—	6.2	.44	.22	3.56	—
Cotton seed meal,	2.4	1.02	.37	.36	—	—	1.8	.77	.28	.27	—
Total conc. food,	10.6	1.61	.66	5.11	4.1	15300	8.0	1.21	.50	3.83	11500
Corn ensilage, -	39.6	.43	.32	6.25	—	—	29.7	.32	.24	4.69	—
Corn stover, -	8.7	.19	.10	4.43	—	—	6.5	.14	.07	3.32	—
Hay, - - -	5.6	.22	.10	2.59	—	—	4.2	.17	.08	1.94	—
Total coarse food,	53.9	.84	.52	13.27	17.2	28450	40.4	.63	.39	9.95	21300
Total food, -	**64.5**	**2.45**	**1.18**	**18.38**	**8.6**	**43750**	**48.4**	**1.84**	**.89**	**13.78**	**32800**
Average per Day for Herd.											
Grain mixture,* -	6.1	.44	.22	3.54	—	—	4.6	.33	.17	2.65	—
Cotton seed meal,	2.5	1.07	.38	.37	—	—	1.9	.80	.28	.28	—
Total conc. food,	8.6	1.51	.60	3.91	3.5	12600	6.5	1.13	.45	2.93	9450
Corn ensilage, -	39.3	.43	.32	6.21	—	—	29.4	.32	.24	4.66	—
Corn stover, -	8.8	.19	.10	4.49	—	—	6.6	.14	.07	3.37	—
Hay, - - -	5.7	.22	.10	2.65	—	—	4.3	.17	.08	1.99	—
Total coarse food,	53.8	.84	.52	13.35	17.3	28600	40.3	.63	.39	10.02	21450
Total food, -	**62.4**	**2.35**	**1.12**	**17.26**	**8.4**	**41200**	**46.8**	**1.76**	**.84**	**12.95**	**30900**

* For proportion of ingredients in the grain mixture, see preceding page.

Table 4.

Dairy Test No. 42.—Statistics of Herd K from January 25, 1897, to February 6, 1897.

Ref. No.	Breed.	Age.	Weight.	Mos. since Last Calf.	Daily Milk Flow. Min.	Daily Milk Flow. Max.	Daily Milk Flow. Avg.	Daily Percentage of Fat. Min.	Daily Percentage of Fat. Max.	Daily Percentage of Fat. Avg.	Daily Yield of Fat. Min.	Daily Yield of Fat. Max.	Daily Yield of Fat. Avg.
		Yrs.	Lbs.	Mos.	Lbs.	Lbs.	Lbs.	%	%	%	Lbs.	Lbs.	Lbs.
1	G. Jy., - -	12	800	5	14.7	18.7	**17.5**	5.0	5.7	**5.2**	.70	1.02	**.91**
2	G. Jy., - -	12	800	3	19.9	24.7	**22.6**	5.0	5.4	**5.2**	1.04	1.26	**1.17**
3	R. Jy., - -	8	725	5	12.6	14.7	**13.7**	6.0	6.4	**6.2**	.77	.88	**.85**
4	G. Jy., - -	12	800	51	12.6	15.0	**13.8**	5.9	6.2	**6.1**	.78	.90	**.84**
5	G. Jy., - -	9	750	3	14.9	17.2	**15.9**	5.5	6.0	**5.8**	.83	1.00	**.91**
6	G. Jy., - -	7	725	5	15.9	20.1	**18.1**	4.8	5.4	**5.1**	.79	1.07	**.92**
7	R. Jy., - -	7	650	5	15.6	18.1	**16.9**	5.4	5.7	**5.6**	.89	1.02	**.95**
8	G. Jy., - -	5	675	2	18.6	23.3	**20.9**	5.0	5.8	**5.3**	.95	1.21	**1.11**
9	G. Jy., - -	2	750	3	12.9	14.8	**14.0**	5.6	6.3	**5.9**	.75	.88	**.83**
	Herd avg.,	—	**750**	—	—	—	**17.0**	—	—	**5.6**	—	—	**.94**

Pounds of food and nutrients per day per 1000 pounds, live weight, and per average weight (750 pounds) of herd.

Kinds of Food.	Per 1000 Lbs., Live Weight. Average Fed per Day.	Digestible Nutrients and Fuel Value. Protein.	Fat.	Carbohydrates.	Nutritive Ratio.	Fuel Value.	Per Average Weight (750 Lbs.) of Herd. Average Fed per Day.	Digestible Nutrients and Fuel Value. Protein.	Fat.	Carbohydrates.	Fuel Value.
	Lbs.	Lbs.	Lbs.	Lbs.	1:	Cal.	Lbs.	Lbs.	Lbs	Lbs.	Cal.
Average per Day.											
Grain mixture,* -	8.1	1.11	.31	3.79	—	—	6.1	.83	.23	2.84	—
Cotton seed meal,	3.0	1.28	.45	.45	—	—	2.2	.96	.34	.34	—
Total conc. food,	11.1	2.39	.76	4.24	2.5	15550	8.3	1.79	.57	3.18	11650
Corn ensilage, -	38.5	.37	.28	4.66	—	—	28.9	.28	.21	3.49	—
Corn stover, -	7.6	.16	.07	3.62	—	—	5.7	.12	.05	2.72	—
Hay, mixed, -	4.1	.16	.06	1.80	—	—	3.1	.12	.05	1.35	—
Total coarse food,	50.2	.69	.41	10.08	16.0	21750	37.7	.52	.31	7.56	16350
Total food, -	**61.3**	**3.08**	**1.17**	**14.32**	**5.5**	**37300**	**46.0**	**2.31**	**.88**	**10.74**	**28000**
Minimum per Day.											
Concentrated food,	10.9	2.37	.75	4.15	2.5	15300	8.2	1.78	.56	3.11	11450
Coarse food, -	49.4	.71	.40	9.91	16.0	21450	37.0	.53	.30	7.43	16100
Total food, -	60.3	3.08	1.15	14.06	5.4	36750	45.2	2.31	.86	10.54	27550
Maximum per Day.											
Concentrated food,	10.8	2.35	.75	4.10	2.5	15150	8.1	1.76	.56	3.08	11350
Coarse food, -	52.8	.71	.43	10.40	16.0	22500	39.6	.53	.33	7.80	16900
Total food, -	63.6	3.06	1.18	14.50	5.6	37650	47.7	2.29	.89	10.88	28250

* For proportion of ingredients in the grain mixture, see page 26.

The studies of the third herd included tests No. 43 and No. 45. The first test, of twelve days duration, began February 8, 1897; the second test, of equal length, began March 8. The cows were watered at a brook about a quarter of a mile distant. During the first test the grain feed was mixed in the proportion of four parts fine wheat feed, four parts Rockford gluten feed, one part corn meal, one part corn and cob meal, and one part old process linseed meal. The corn stover was fed without cutting into short lengths and a large amount of butts was left uneaten. It was estimated that about 140 pounds of butts were removed from the mangers during the test, or an average of about 1.3 pounds per cow per day. The composition of these was assumed from analyses of corn stover butts left in sheep feeding experiments. In calculating the results, the nutrients rejected in the butts were subtracted from the total nutrients in the feeding stuffs actually fed.

The cows were not all fed alike. Cows 7 and 9 had corn and cob meal, and cow 8 linseed meal substituted for a portion of the grain mixture. In the following table the average nutrients fed each group of cows is shown, as well as the average amounts for the whole herd.

TABLE 5.

Dairy Test No. 43.—Statistics of Herd L from February 8, 1897, to February 20, 1897.

Ref. No.	Breed.	Age.	Weight.	Mos. since Last Calf.	Daily Milk Flow.			Daily Percentage of Fat.			Daily Yield of Fat.		
					Min.	Max.	Avg.	Min.	Max.	Avg.	Min.	Max.	Avg.
		Yrs.	Lbs.	Mos.	Lbs.	Lbs.	Lbs.	%	%	%	Lbs.	Lbs.	Lbs.
1	Native, - -	7	700	3	30.5	34.4	**32.1**	4.4	4.7	**4.5**	1.36	1.55	**1.45**
2	Native, - -	6	850	6	17.8	19.3	**18.8**	4.0	4.6	**4.3**	.74	.88	**.81**
3	G. Jy., - -	9	850	4	26.2	30.6	**28.4**	4.1	4.7	**4.4**	1.16	1.32	**1.24**
4	G. Jy., - -	6	675	5	17.7	20.4	**18.9**	5.4	6.4	**6.0**	1.08	1.22	**1.13**
5	G. Hol., -	9	850	3	18.5	27.7	**25.1**	4.0	5.6	**4.5**	.97	1.26	**1.11**
6	G. Jy., - -	6	750	4	15.6	20.3	**17.7**	5.4	6.5	**5.7**	.84	1.22	**1.02**
	Avg., -	—	**775**	—	—	—	**23.5**	—	—	**4.9**	—	—	**1.13**
7	G. Jy., - -	7	775	5	15.0	17.4	**15.7**	5.6	6.4	**5.9**	.86	1.06	**.92**
9	G. Jy., - -	9	775	3	18.4	24.6	**20.4**	4.4	5.0	**4.7**	.81	1.11	**.96**
	Avg., -	—	**775**	—	—	—	**18.1**	—	—	**5.3**	—	—	**.94**
8	Native, - -	11	750	—	19.0	24.4	**22.2**	5.1	6.0	**5.5**	1.15	1.39	**1.24**
	Herd avg., -	—	**775**	—	—	—	**22.1**	—	—	**5.1**	—	—	**1.10**

TABLE 5.—*(Continued.)*

Pounds of food and nutrients per day per 1000 pounds, live weight, and per average weight (775 pounds) of herd.

Kinds of Food.	Per 1000 Lbs., Live Weight.						Per Average Weight (775 Lbs.) of Herd.				
	Average Fed per Day.	Digestible Nutrients and Fuel Value.					Average Fed per Day.	Digestible Nutrients and Fuel Value.			
		Protein.	Fat.	Carbo-hydrates.	Nutritive Ratio.	Fuel Value.		Protein.	Fat.	Carbo-hydrates.	Fuel Value.
Cows 1, 2, 3, 4, 5, 6.	Lbs.	Lbs.	Lbs	Lbs.	1:	Cal.	Lbs.	Lbs.	Lbs	Lbs.	Cal.
Average per Day.											
Grain mixture,*	14.4	2.43	.66	7.25	3.7	20800	11.1	1.89	.51	5.62	16100
Corn stover,	9.0	.26	.07	3.82	—	—	7.0	.20	.05	2.96	—
Oat straw,	5.4	.09	.08	2.00	—	—	4.2	.07	.06	1.55	—
Turnips,	5.4	.05	.01	.37	—	—	4.2	.04	.01	.29	—
Total coarse food,	19.8	.40	.16	6.19	16.3	12900	15.4	.31	.12	4.80	10000
Total food,	34.2	2.83	.82	13.44	5.4	33700	26.5	2.20	.63	10.42	26100
Uneaten stover butts,	1.3	.05	.02	.68	—	1400	1.0	.04	.02	.53	1150
Total eaten,	**32.9**	**2.78**	**.80**	**12.76**	**5.2**	**32300**	**25.5**	**2.16**	**.61**	**9.89**	**24950**
Cows 7 and 9.											
Average per Day.											
Grain mixture,*	8.4	1.42	.38	4.23	—	—	6.5	1.10	.29	3.28	—
Corn and cob meal,	8.4	.66	.29	5.19	—	—	6.5	.51	.23	4.02	—
Total conc. food,	16.8	2.08	.67	9.42	5.3	24200	13.0	1.61	.52	7.30	18750
Corn stover,	9.0	.26	.07	3.82	—	—	7.0	.20	.05	2.96	—
Oat straw,	5.4	.09	.08	2.00	—	—	4.2	.07	.06	1.55	—
Turnips,	5.4	.05	.01	.37	—	—	4.1	.04	.01	.29	—
Total coarse food,	19.8	.40	.16	6.19	16.5	12950	15.3	.31	.12	4.80	10000
Total food,	36.6	2.48	.83	15.61	7.1	37150	28.3	1.92	.64	12.10	28750
Uneaten stover butts,	1.3	.05	.02	.68	—	1400	1.0	.04	.02	.53	1150
Total eaten,	**35.3**	**2.43**	**.81**	**14.93**	**6.9**	**35750**	**27.3**	**1.88**	**.62**	**11.57**	**27600**
Cow 8.											
Average per Day.											
Grain mixture,*	9.9	1.68	.45	4.98	—	—	7.4	1.26	.34	3.74	—
Linseed meal,	2.9	.98	.22	.85	—	—	2.2	.74	.16	.64	—
Total conc. food,	12.8	2.66	.67	5.83	2.8	18600	9.6	2.00	.50	4.38	14000
Corn stover,	9.3	.27	.07	3.95	—	—	7.0	.20	.05	2.96	—
Oat straw,	5.6	.10	.08	2.07	—	—	4.2	.07	.06	1.55	—
Turnips,	5.6	.05	.01	.39	—	—	4.2	.04	.01	.29	—
Total coarse food,	20.5	.42	.16	6.41	16.2	13400	15.4	.31	.12	4.80	10000
Total food,	33.3	3.08	.83	12.24	4.6	32000	25.0	2.31	.62	9.18	24000
Uneaten stover butts,	1.3	.05	.02	.68	—	1400	1.0	.04	.02	.53	1150
Total eaten,	**32.0**	**3.03**	**.81**	**11.56**	**4.4**	**30600**	**24.0**	**2.27**	**.60**	**8.65**	**22850**
Average per Day for Herd.											
Total conc. food,	14.7	2.38	.66	7.57	3.8	21300	11.4	1.84	.51	5.87	16500
Total coarse food,	19.9	.40	.16	6.21	16.3	12950	15.4	.31	.13	4.81	10050
Total food,	34.6	2.78	.82	13.78	5.6	34250	26.8	2.15	.64	10.68	26550
Uneaten stover butts,	1.3	.05	.02	.68	—	1400	1.0	.04	.02	.53	1150
Total eaten,	**33.3**	**2.73**	**.80**	**13.10**	**5.5**	**32850**	**25.8**	**2.11**	**.62**	**10.15**	**25400**

* For proportion of ingredients in the grain mixture, see preceding page.

In the Annual Report of this Station for 1896, pages 69–84, considerable stress was laid upon the principle that rations for milch cows should be regulated by the milk yield, rather than by the live weight of the animal. In this experiment the main idea was to change the feeding in such a manner as would not only give a ration with a narrower nutritive ratio, but to vary this for the different animals of the herd in accordance with their milk production. Accordingly two grain mixtures were prepared, one of which should be fed equally to all the herd and the other in proportion to the daily milk flow. Mixture No. 1, fed to each cow, was made up of two parts wheat bran, two parts wheat middlings, three parts Chicago gluten meal, and one part Rockford gluten feed. Mixture No. 2 was composed of one part Chicago gluten meal, and one part old process linseed meal. The following directions for feeding were given: Feed mixture No. 1 equally to each cow of the herd; for cows giving less than nine quarts of milk daily (cow 7) feed two pounds of mixture No. 2; for cows giving from nine to thirteen quarts of milk (cows 2, 4, 6, and 9,) feed three pounds of mixture No. 2; for cows giving more than thirteen quarts of milk (cows 1, 3, 5, and 8,) feed four pounds of mixture No. 2. The statistics for the whole herd and for the subdivisions according to milk flow are given in the following table:

TABLE 6.

Dairy Test No. 45.—Statistics of Herd L from March 8, 1897, to March 20, 1897.

Ref. No.	Breed.	Age.	Weight.	Mos. since Last Calf.	Daily Milk Flow.			Daily Percentage of Fat.			Daily Yield of Fat.		
					Min.	Max.	Avg.	Min.	Max.	Avg.	Min.	Max.	Avg.
		Yrs.	Lbs.	Mos.	Lbs.	Lbs.	Lbs.	%	%	%	Lbs.	Lbs.	Lbs.
7	G. Jy., - -	7	775	6	14.1	17.0	**14.9**	5.2	6.5	**5.9**	.80	.97	**.88**
2	Native, - -	6	850	7	18.5	21.5	**19.9**	4.1	4.5	**4.3**	.80	.91	**.85**
4	G. Jy., - -	6	675	6	18.4	21.6	**19.5**	5.7	6.6	**6.1**	1.10	1.27	**1.19**
6	G. Jy., - -	6	750	5	15.3	20.9	**17.8**	5.4	6.2	**5.9**	.93	1.08	**1.04**
9	G. Jy., - -	9	775	4	13.8	22.0	**19.5**	5.1	6.0	**5.7**	.83	1.22	**1.10**
	Avg., -	—	**775**	—	—	—	**19.2**	—	—	**5.5**	—	—	**1.05**
1	Native, - -	7	700	4	30.1	32.6	**31.3**	4.0	4.6	**4.3**	1.24	1.50	**1.35**
3	G. Jy., - -	9	850	5	27.8	31.9	**29.4**	4.2	4.9	**4.5**	1.21	1.47	**1.32**
5	G. Hol., -	9	850	4	22.6	27.0	**24.5**	4.0	4.6	**4.2**	.96	1.15	**1.04**
8	Native, - -	11	750	1	31.3	35.6	**33.4**	4.0	4.8	**4.4**	1.38	1.58	**1.48**
	Avg., -	—	**775**	—	—	—	**29.7**	—	—	**4.4**	—	—	**1.30**
	Herd avg., -	—	**775**	—	—	—	**23.4**	—	—	**5.0**	—	—	**1.14**

TABLE 6.—(*Continued.*)

Pounds of food and nutrients per day per 1000 pounds, live weight, and per average weight (775 pounds) of herd.

Kinds of Food.	Per 1000 Lbs., Live Weight.						Per Average Weight (775 Lbs.) of Herd.				
	Average Fed per Day.	Digestible Nutrients and Fuel Value.					Average Fed per Day.	Digestible Nutrients and Fuel Value.			
		Protein.	Fat.	Carbo-hydrates.	Nutritive Ratio.	Fuel Value.		Protein.	Fat.	Carbo-hydrates.	Fuel Value.
Cows 2, 4, 6, 9. *Average per Day.*	Lbs.	Lbs.	Lbs	Lbs.	1:	Cal.	Lbs.	Lbs.	Lbs	Lbs.	Cal.
Grain mixture No. 1,*	10.5	2.39	.54	4.37	—	—	8.1	1.85	.42	3.39	—
Grain mixture No. 2,*	4.1	1.41	.27	1.36	—	—	3.2	1.09	.21	1.05	—
Total conc. food,	14.6	3.80	.81	5.73	2.0	21150	11.3	2.94	.63	4.44	16400
Oat straw, - -	5.8	.10	.07	2.11	—	—	4.5	.08	.05	1.63	—
Corn stover, - -	9.4	.26	.06	3.84	—	—	7.3	.20	.05	2.98	—
Total coarse food,	15.2	.36	.13	5.95	17.4	12300	11.8	.28	.10	4.61	9500
Total food, - -	**29.8**	**4.16**	**.94**	**11.68**	**3.3**	**33450**	**23.1**	**3.22**	**.73**	**9.05**	**25900**
Cows 1, 3, 5, 8. *Average per Day.*											
Grain mixture No. 1,*	10.1	2.29	.51	4.21	—	—	7.8	1.78	.39	3.26	—
Grain mixture No. 2,*	5.1	1.76	.33	1.70	—	—	3.9	1.36	.26	1.32	—
Total conc. food,	15.2	4.05	.84	5.91	1.9	22050	11.7	3.14	.65	4.58	17100
Oat straw, - -	5.7	.10	.07	2.07	—	—	4.4	.08	.05	1.60	—
Corn stover, - -	9.1	.25	.05	3.82	—	—	7.1	.19	.04	2.96	—
Total coarse food,	14.8	.35	.12	5.89	17.6	12100	11.5	.27	.09	4.56	9350
Total food, - -	**30.0**	**4.40**	**.96**	**11.80**	**3.2**	**34150**	**23.2**	**3.41**	**.74**	**9.14**	**26450**
Cow 7. *Average per Day.*											
Grain mixture No. 1,*	10.3	2.34	.52	4.30	—	—	8.0	1.81	.40	3.33	—
Grain mixture No. 2,*	2.6	.90	.17	.86	—	—	2.0	.70	.13	.67	—
Total conc. food,	12.9	3.24	.69	5.16	2.1	18550	10.0	2.51	.53	4.00	14350
Oat straw, - -	5.6	.10	.07	2.03	—	—	4.3	.08	.05	1.57	—
Corn stover, - -	9.3	.25	.06	3.91	—	—	7.2	.19	.05	3.03	—
Total coarse food,	14.9	.35	.13	5.94	17.8	12250	11.5	.27	.10	4.60	9500
Total food, - -	**27.8**	**3.59**	**.82**	**11.10**	**3.6**	**30800**	**21.5**	**2.78**	**.63**	**8.60**	**23850**
Average per Day for Herd.											
Grain mixture No. 1,*	10.3	2.34	.53	4.30	—	—	8.0	1.81	.41	3.34	—
Grain mixture No. 2,*	4.4	1.51	.28	1.46	—	—	3.4	1.17	.22	1.13	—
Total conc. food, -	14.7	3.85	.81	5.76	2.0	21300	11.4	2.98	.63	4.47	16500
Oat straw, - -	5.7	.10	.07	2.07	—	—	4.4	.08	.05	1.60	—
Corn stover, - -	9.3	.26	.06	3.91	—	—	7.2	.20	.05	3.03	—
Total coarse food,	15.0	.36	.13	5.98	17.4	12350	11.6	.28	.10	4.63	9550
Total food, - -	**29.7**	**4.21**	**.94**	**11.74**	**3.3**	**33650**	**23.0**	**3.26**	**.73**	**9.10**	**26050**

* For proportion of ingredients in the grain mixture, see preceding page.

The observations for the last herd studied during the winter of 1896–97 are designated as tests No. 44 and No. 46.

TABLE 7.

Dairy Test No. 44.—Statistics of Herd M from February 22, 1897, to March 6, 1897.

Ref. No.	BREED.	Age.	Weight.	Mos. since Last Calf.	DAILY MILK FLOW.			DAILY PERCENTAGE OF FAT.			DAILY YIELD OF FAT.		
					Min.	Max.	Avg.	Min.	Max.	Avg.	Min.	Max.	Avg.
		Yrs.	Lbs.	Mos.	Lbs.	Lbs.	Lbs.	%	%	%	Lbs.	Lbs.	Lbs.
1	P. Jy., - -	6	700	2	28.1	33.1	**29.4**	4.0	4.7	**4.3**	1.12	1.50	**1.28**
2	P. Jy., - -	7	775	2	29.4	32.3	**31.3**	3.6	4.6	**4.2**	1.16	1.39	**1.31**
3	P. Jy., - -	6	750	1	25.0	27.4	**26.3**	4.8	5.2	**5.0**	1.24	1.40	**1.31**
4	P. Jy., - -	8	775	1	19.4	21.8	**20.7**	5.2	5.6	**5.5**	1.01	1.22	**1.13**
5	G. Jy., - -	9	800	4	19.9	23.8	**22.2**	3.0	4.7	**4.5**	.65	1.10	**1.00**
6	P. Jy., - -	6	750	2	28.3	32.7	**30.7**	3.8	5.2	**4.7**	1.19	1.59	**1.45**
7	G. Jy., - -	2	500	1	8.8	10.1	**9.5**	4.2	5.0	**4.6**	.41	.51	**.44**
8	P. Jy., - -	5	850	8	11.5	13.0	**12.2**	5.4	6.1	**5.7**	.62	.75	**.70**
	Herd avg.,	—	**725**	—	—	—	**22.8**	—	—	**4.8**	—	—	**1.08**

Pounds of food and nutrients per day per 1000 pounds, live weight, and per average weight (725 pounds) of herd.

KINDS OF FOOD.	PER 1000 LBS., LIVE WEIGHT.						PER AVERAGE WEIGHT (725 LBS.) OF HERD.				
	Average Fed per Day.	DIGESTIBLE NUTRIENTS AND FUEL VALUE.					Average Fed per Day.	DIGESTIBLE NUTRIENTS AND FUEL VALUE.			
		Protein.	Fat.	Carbo-hydrates.	Nutritive Ratio.	Fuel Value.		Protein.	Fat.	Carbo-hydrates.	Fuel Value.
Average per Day.	Lbs.	Lbs.	Lbs.	Lbs.	1:	Cal.	Lbs.	Lbs.	Lbs	Lbs.	Cal.
Buffalo gluten feed,	6.7	1.52	.66	3.04	—	—	4.9	1.10	.48	2.20	—
Corn and cob meal,	9.6	.65	.27	5.44	—	—	6.9	.47	.19	3.95	—
Total conc. food,	16.3	2.17	.93	8.48	4.9	23700	11.8	1.57	.67	6.15	17200
Mixed hay, - -	10.1	.33	.15	4.38	—	—	7.3	.24	.11	3.18	—
Oat hay, - -	8.7	.37	.16	3.01	—	—	6.3	.27	.12	2.18	—
Bog hay, - -	1.9	.06	.02	.72	—	—	1.4	.04	.01	.52	—
Total coarse food,	20.7	.76	.33	8.11	11.7	17900	15.0	.55	.24	5.88	12950
Total food, -	**37.0**	**2.93**	**1.26**	**16.59**	**6.6**	**41600**	**26.8**	**2.12**	**.91**	**12.03**	**30150**
Minimum per Day.											
Concentrated food,	15.4	2.11	.91	7.96	4.8	22550	11.2	1.53	.66	5.77	16350
Coarse food, -	19.3	.72	.31	7.61	11.5	16800	14.0	.52	.22	5.52	12150
Total food, -	34.7	2.83	1.22	15.57	6.5	39350	25.2	2.05	.88	11.29	28500
Maximum per Day.											
Concentrated food,	16.4	2.17	.94	8.53	4.9	23850	11.9	1.57	.68	6.18	17300
Coarse food, -	24.7	.90	.35	9.64	11.6	21100	17.9	.66	.26	6.99	15300
Total food, -	41.1	3.07	1.29	18.17	6.9	44950	29.8	2.23	.94	13.17	32600

TABLE 8.

Dairy Test No. 46.—Statistics of Herd M from March 22, 1897, to April 1, 1897.

Ref. No.	Breed.	Age.	Weight.	Mos. since Last Calf.	Daily Milk Flow. Min.	Max.	Avg.	Daily Percentage of Fat. Min.	Max.	Avg.	Daily Yield of Fat. Min.	Max.	Avg.
		Yrs.	Lbs.	Mos.	Lbs.	Lbs.	Lbs.	%	%	%	Lbs.	Lbs.	Lbs.
1	P. Jy., - -	6	700	2	26.4	29.1	**27.5**	4.6	5.1	**4.8**	1.23	1.46	**1.32**
2	P. Jy., - -	7	775	2	26.9	29.3	**28.5**	3.2	5.2	**4.3**	.94	1.48	**1.24**
3	P. Jy., - -	6	750	1	22.9	25.9	**24.5**	5.0	5.6	**5.3**	1.23	1.38	**1.31**
4	P. Jy., - -	8	775	1	19.1	23.1	**20.2**	5.4	6.3	**5.9**	1.07	1.32	**1.18**
5	G. Jy., - -	9	800	4	19.2	23.0	**20.7**	4.4	5.5	**5.0**	.85	1.17	**1.04**
6	P. Jy., - -	6	750	2	25.5	32.0	**28.2**	4.3	5.6	**5.0**	1.21	1.76	**1.42**
7	G. Jy., - -	2	500	1	10.0	11.9	**10.8**	4.6	5.2	**5.0**	.51	.58	**.54**
8	P. Jy., - -	5	850	8	9.5	12.7	**10.8**	5.3	6.8	**6.1**	.57	.75	**.65**
	Herd avg.,	—	**725**	—	—	—	**21.4**	—	—	**5.2**	—	—	**1.09**

Pounds of food and nutrients per day per 1000 pounds, live weight, and per average weight (725 pounds) of herd.

Kinds of Food.	Per 1000 Lbs., Live Weight. Average Fed per Day.	Digestible Nutrients and Fuel Value. Protein.	Fat.	Carbo-hydrates.	Nutritive Ratio.	Fuel Value.	Per Average Weight (725 Lbs.) of Herd. Average Fed per Day.	Digestible Nutrients and Fuel Value. Protein.	Fat.	Carbo-hydrates.	Fuel Value.
Average per Day.	Lbs.	Lbs.	Lbs.	Lbs.	1:	Cal.	Lbs.	Lbs.	Lbs	Lbs.	Cal.
Chic. gluten meal,	8.0	2.86	.48	3.04	—	—	5.8	2.07	.35	2.20	—
Corn and cob meal,	7.7	.59	.28	4.55	—	—	5.6	.43	.20	3.30	—
Total conc. food,	15.7	3.45	.76	7.59	2.7	23750	11.4	2.50	.55	5.50	17200
Mixed hay, - -	8.3	.34	.20	3.81	—	—	6.0	.24	.15	2.76	—
Oat hay, - -	10.1	.52	.20	3.56	—	—	7.3	.38	.14	2.58	—
Total coarse food,	18.4	.86	.40	7.37	9.6	17000	13.3	.62	.29	5.34	12300
Total food, -	**34.1**	**4.31**	**1.16**	**14.96**	**4.1**	**40750**	**24.7**	**3.12**	**.84**	**10.84**	**29500**
Minimum per Day.											
Concentrated food,	15.7	3.45	.76	7.59	2.7	23750	11.4	2.50	.55	5.50	17200
Coarse food, -	17.8	.83	.39	7.16	9.7	16500	12.9	.60	.28	5.19	11950
Total food, -	33.5	4.28	1.15	14.75	4.1	40250	24.3	3.10	.83	10.69	29150
Maximum per Day.											
Concentrated food,	15.7	3.45	.76	7.59	2.7	23750	11.4	2.50	.55	5.50	17200
Coarse food, -	18.8	.88	.41	7.52	9.6	17350	13.6	.64	.30	5.45	12600
Total food, -	34.5	4.33	1.17	15.11	4.1	41100	25.0	3.14	.85	10.95	29800

The first test began February 22, the second test one month later. Each continued for twelve days. The cows were watered

once a day from a trough in the yard. The grains fed in the test were Buffalo gluten feed and corn and cob meal. In the second test Chicago gluten meal was substituted for the Buffalo gluten feed. In each case the grains were fed independently, and not in a mixture as in several of the rations. With the exception of two cows which refused to eat the Chicago gluten meal in the second test, and which for that reason are omitted in the tables, there were no considerable irregularities to interfere with the results of the test.

DISCUSSION OF THE EXPERIMENTS OF THE WINTER OF 1896–97.

The cost of the feeding stuffs, the pecuniary results of the experiments, the rations fed, and the physiological effects resulting from their use are briefly discussed in the following pages.

The figures used for estimating the values of the feeding stuffs, *i. e.*, the market prices per ton and the values of manure obtainable from one ton of each of the feeding stuffs are stated in the accompanying table:

Valuation of feeding stuffs as used in rations fed milch cows in winter of 1896–97.

Kind of Feeding Stuffs.	Market Price per Ton of Feeding Stuffs.	Estimated Value of the Manure Obtainable from One Ton of Feeding Stuffs.
Chicago gluten meal,	$17.50	$11.00
Rockford gluten feed,	15.00	6.50
Buffalo gluten feed,	15.00	7.00
Cotton seed meal,	22.00	15.00
O. P. linseed meal,	25.00	12.00
Rye meal,	22.00	4.00
Corn and cob meal,	12.00	3.50
Wheat bran,	14.00	7.00
Wheat middlings,	15.00	6.50
Fine wheat feed,	15.00	6.50
Corn meal,	15.00	4.00
Ground oats,	22.00	10.50
Corn ensilage,	3.00	1.00
Corn stover,	6.00	2.50
Potatoes,	10c. per bu.	—
Turnips,	10c. per bu.	—
Hay (mixed grasses),	12.00	3.50
Bog hay,	8.00	3.00
Oat hay,	10.00	4.00
Oat straw,	8.00	4.00

The prices of the feeding stuffs used in calculating the cost of rations were those current in December, 1897. They were obtained, in the case of the grain feeds, by sending inquiries to grain dealers in five Connecticut cities asking the current prices of grains in ton lots, and averaging the figures thus obtained. The coarse fodders are based upon the market value of the various materials as estimated by farmers. The manurial value is based upon figures given in the article on Nitrogenous Feeding Stuffs beyond. It is assumed that 75 per cent. of the nitrogen, phosphoric acid, and potash of the feeding stuffs may be saved in the manure. Unfortunately, most farmers take such poor care of the manure produced from the materials fed to their stock, that a much smaller percentage is usually saved. The manurial value of the humus and other organic matters, as such, is not taken into account in these estimates, although it is at times very considerable.

DAIRY HERD J.—TESTS 39 AND 41.

The tests on this herd were made in December and January, with an interval of about two weeks between the tests. Thirteen cows were included in the tests; the animals were the same in both cases. They were all grade Jerseys with the exception of one, which was a Jersey-Guernsey cross. The estimated average weight of the animals in the herd was 725 pounds, and the average age was 6 years. At the date of the first test the average time since last calf was 4 months. None of the animals were due to calve until 6 months or more after the close of the second test. The rations actually fed are shown in the following table. The main changes between the first and the second ration were the substitution of wheat bran for corn meal, the addition of cottonseed meal in place of part of the Buffalo gluten feed, and a reduction in the amounts of hay. This increased the amount and its proportion of protein to carbohydrates and thus reduced the nutritive ratio from 1:8 to about 1:5. The average daily cost of the ration was reduced from 16.3 cents to 14.6 cents. The average daily yield of milk was less by .5 of a pound in the second test than in the first, but the daily yield of butter was larger by .05 of a pound. The total cost of food to produce a hundred pounds of milk was reduced seven cents, and the cost of feed for one pound of

butter was reduced three cents in the second test (see table 10). Although the quantity of milk produced per day was slightly less in the second test than in the first, the quality of the milk was enough improved to more than make up for the loss in quantity. The second ration would have been fully as economical as the first even had the value of the coarse fodders remained the same in each, because the increase in the cost of the second grain ration (one cent) was covered by the increased quantity of butter, estimating the butter at twenty cents per pound.

Dairy Herd J.—Tests 39 and 41.—Calculated per average weight of herd (725 pounds).

Feeding Stuffs.		Digestible Nutrients and Fuel Value.							
Kind.	Amount.	Protein.	Fat.	Carbo-hydrates.	Fuel Value.	Nutritive Ratio.	Cost.	Value of Obtainable Manure.	Net Cost.
First Test.	Lbs.	Lbs.	Lbs.	Lbs.	Cal.	1:	Cts.	Cts.	Cts.
Dec. 14 to Dec. 26, 1896. 12 Days.									
Grain, etc., Corn meal,	3.2	1.11	.23	3.94	10350	4.0	5.5	2.1	3.4
Buffalo gluten feed,	4.1								
Hays, etc., Corn ensilage,	28.4	.70	.35	9.31	20100	14.4	10.8	3.7	7.1
Oat hay,	6.3								
Hay,	3.4								
Potatoes,	8.3								
Total food,	**53.7**	**1.81**	**.58**	**13.25**	**30450**	**8.0**	**16.3**	**5.8**	**10.5**
Second Test.									
Jan. 11 to Jan. 23, 1897. 12 Days.									
Grain, etc., Buffalo gluten feed,	3.7	1.85	.38	2.92	10500	2.1	6.6	3.6	3.0
Wheat bran,	2.7								
Cotton seed meal,	1.8								
Hays, etc., Corn ensilage,	28.4	.59	.35	7.83	17100	14.5	8.0	2.7	5.3
Oat hay,	4.1								
Hay,	2.8								
Total food,	**43.5**	**2.44**	**.73**	**10.75**	**27600**	**5.1**	**14.6**	**6.3**	**8.3**

DAIRY HERD K.—TESTS 40 AND 42.

The first test made on this herd was begun December 28, and the second ended February 6. Nine cows were used in the tests—seven grade and two registered Jerseys. The average estimated weight of the cows was 750 pounds, the average age 8½ years. All of the cows except one, which was farrow, had quite recently calved. The ration fed in the first test was considerably below the commonly accepted standards in protein and

had a wide nutritive ratio. In the second test the nutritive ratio was made to accord with our suggested standard, while the protein was slightly above that suggested by this Station for animals of the average live weight of this herd. The main change in the second ration was the omission of rye meal, ground oats, and part of the corn meal, which were deemed relatively expensive, and the substitution therefor of cottonseed meal and Chicago gluten. The total cost of the first ration was 15.6 cents, and of the second ration 14.9 cents per cow per day. The second grain ration cost four-tenths of a cent per day more than the first, while the coarse fodders cost about one cent less in the case of the second ration. The average milk yield was essentially the same in each of the tests, while the yield of butter fat was .07 of a pound more per day in the case of the second ration. (See table 10.)

Dairy Herd K.—Tests 40 and 42.—Calculated per average weight of herd (750 pounds).

Feeding Stuffs.			Digestible Nutrients and Fuel Value.							
Kind.		Amount.	Protein.	Fat.	Carbohydrates.	Fuel Value.	Nutritive Ratio.	Cost.	Value of Obtainable Manure.	Net Cost.
		Lbs.	Lbs.	Lbs.	Lbs.	Cal.	1:	Cts.	Cts.	Cts.
First Test. *Dec. 28, '96, to Jan. 9, '97. 12 Days.*										
Grain, etc.,	Corn meal,	3.1								
	Wheat bran,	1.2								
	Ground oats,	.2	1.13	.45	2.93	9450	3.5	6.6	2.6	4.0
	Rye meal,	.1								
	Cotton seed meal,	1.9								
Hays, etc.,	Corn ensilage,	29.4								
	Corn stover,	6.6	.63	.39	10.02	21450	17.3	9.0	3.0	6.0
	Hay, mixed grasses,	4.3								
Total food,		**46.8**	**1.76**	**.84**	**12.95**	**30900**	**8.4**	**15.6**	**5.6**	**10.0**
Second Test. *Jan. 25 to Feb. 6, 1897. 12 Days.*										
Grain, etc.,	Wheat bran,	3.7								
	Corn meal,	1.2								
	Chic. gluten meal,	1.2	1.79	.57	3.18	11650	2.5	7.0	3.8	3.2
	Cotton seed meal,	2.2								
Hays, etc.,	Corn ensilage,	28.9								
	Corn stover,	5.7	.52	.31	7.56	16350	16.0	7.9	2.7	5.2
	Hay, mixed grasses,	3.1								
Total food,		**46.0**	**2.31**	**.88**	**10.74**	**28000**	**5.5**	**14.9**	**6.5**	**8.4**

DAIRY HERD L.—TESTS 43 AND 45.

The tests made on this herd were carried out during February and March, with the usual interval between the tests. There were nine cows in each test—five grade Jerseys, three natives, and a grade Holstein. The average estimated weight of the cows was 775 pounds. The average age was eight years.

At the beginning of the first test the average time since producing the last calf was 3½ months. The ration fed in the first test was a narrow one and fully up to the standard heretofore recommended by this Station for cows of the average weight of those in this herd. As the milk yields of different cows differed widely, it was thought advisable in the second test to compound a ration which should be regulated by the milk flow. For this purpose two mixtures were prepared. No. 1 was to be fed to all cows of the herd alike, while No. 2 was to be fed in larger or smaller quantities in accordance with the milk flow. Mixture No. 2 was composed of concentrated nitrogenous by-products, and was intended to increase the protein quite rapidly for the heavier milk producers. All cows giving from 10 to 20 pounds of milk per day were fed mixture No. 1 (see table), and in addition two pounds of mixture No. 2. Cows giving from 20 to 26 pounds had mixture No. 1 and three pounds of mixture No. 2 in addition, while cows giving from 26 to 32 pounds had No. 1 and four pounds of No. 2. It will be seen from the average ration given below that the second ration was an exceptionally heavy one in protein. It will also be noticed by reference to the formulas for feeding in accordance with the milk flow given in the following article, that the herd had larger quantities of protein than are there recommended for cows with a corresponding milk flow. Notwithstanding the heavy protein ration fed, the average milk flow for the nine cows in the second test was 1.3 pounds per day greater than in the first test, while the cost of the second ration was six-tenths of a cent more per day. (See table 10.) This farmer was producing milk for the Boston market, and at the average price (three cents per quart) the increase in milk flow in the case of the second ration more than covered the additional cost. For most of the cows, however, the increase was very slight, and we are inclined to doubt if the feeding of as

large quantities of protein as were here used would be economical, except in the case of very heavy milkers.

Dairy Herd L.—Tests 43 and 45.—Calculated per average weight of herd (775 pounds).

Feeding Stuffs.		Digestible Nutrients and Fuel Value.							
Kind.	Amount.	Protein.	Fat.	Carbohydrates.	Fuel Value.	Nutritive Ratio.	Cost.	Value of Obtainable Manure.	Net Cost.
	Lbs.	Lbs.	Lbs.	Lbs.	Cal.	1:	Cts.	Cts.	Cts.
First Test.									
Feb. 8 to Feb. 20, 1897. 12 Days.									
Grain, etc., Fine wheat feed,	4.2								
Grain, etc., Rockf'd gluten feed	4.2								
Grain, etc., Corn and cob meal,	1.0	1.84	.51	5.87	16500	3.8	8.9	3.7	5.2
Grain, etc., Corn meal,	1.0								
Grain, etc., O. P. linseed meal,	1.0								
Hays, etc., Corn stover,	6.0								
Hays, etc., Oat straw,	4.2	.27	.11	4.28	8900	16.7	4.3	1.8	2.5
Hays, etc., Turnips,	4.2								
Total food,	**25.8**	**2.11**	**.62**	**10.15**	**25400**	**5.5**	**13.2**	**5.5**	**7.7**
Second Test.									
Mar. 8 to Mar. 20, '97. 12 Days.									
Mixt'r No. 1, Wheat bran,	2.0								
Mixt'r No. 1, Wheat middlings,	2.0								
Mixt'r No. 1, Chic. gluten meal,	3.0	1.81	.41	3.34					
Mixt'r No. 1, Rockf'd gluten feed	1.0				16500	2.0	9.9	5.3	4.6
Mixt'r No. 2, Chic. gluten meal,	1.7	1.17	.22	1.13					
Mixt'r No. 2, O. P. linseed meal,	1.7								
Hays, etc., Oat straw,	4.4	.28	.10	4.63	9550	17.4	3.9	1.8	2.1
Hays, etc., Corn stover,	7.2								
Total food,	**23.0**	**3.26**	**.73**	**9.10**	**26050**	**3.3**	**13.8**	**7.1**	**6.7**

DAIRY HERD M.—TESTS 44 AND 46.

The tests on this herd were made during February and March, with the usual interval between the tests. There were eight cows in each of the tests, six being pure Jerseys and two grade Jerseys. The average estimated weight of the animals was 725 pounds, the average age was 8 years, and, at the beginning of the first test, the average time since producing the last calf was about 2⅓ months. The ration fed in the first test was as heavy, and as large in protein as is commonly recommended for cows of this weight. The protein was purposely increased by a large amount (one pound per day) in the second test, and the nutritive ratio was thus made quite narrow. Both rations seem to have been well eaten by the cows,

although the milk flow in the second test for some reason dropped off to an unusual degree. The general tendency of rations high in protein in nearly all of our experiments has been to keep up the milk flow and lessen the natural shrinkage. The average percentage of butter-fat in the second test was increased by four-tenths of one per cent. This made the total yields of butter-fat about equal in the two tests. The total cost of the second ration was slightly less than that of the first ration. For the production of milk this second ration, however, proved unprofitable. (See table 10.) We can hardly ascribe the shrinkage in milk flow to any aversion of the cows to the fodder. The cows seemed to eat their rations readily. We have much yet to learn, however, regarding the palatability of different feeds, and it is possible that the grain ration fed in the second test may not have been relished by the cows as well as that fed in the first test. Of course the relatively small milk yield with this ration may be due to causes not yet understood. The relations of large amounts of protein to the milk production and the health of the animal is a subject which demands careful study.

Dairy Herd M.—Tests 44 and 46.—Calculated per average weight of herd (725 pounds).

Feeding Stuffs.			Digestible Nutrients and Fuel Value.							
Kind.		Amount.	Protein.	Fat.	Carbo-hydrates.	Fuel Value.	Nutritive Ratio.	Cost.	Value of Obtainable Manure.	Net Cost.
		Lbs.	Lbs.	Lbs.	Lbs.	Cal.	1:	Cts.	Cts.	Cts.
First Test.										
Feb. 22 to Mar. 6, '97. 12 Days.										
Grain, etc.,	Buffalo gluten feed,	4.9	1.57	.67	6.15	17200	4.9	7.8	2.9	4.9
	Corn and cob meal,	6.9								
Hays, etc.,	Hay, mixed grasses,	7.3	.55	.24	5.88	12950	11.7	8.1	2.7	5.4
	Oat hay, - -	6.3								
	Bog hay, - -	1.4								
Total food, - - -		**26.8**	**2.12**	**.91**	**12.03**	**30150**	**6.6**	**15.9**	**5.6**	**10.3**
Second Test.										
Mar. 22 to Apr. 1, '97. 10 Days.										
Grain, etc.,	Chic. gluten meal,	5.8	2.50	.55	5.50	17200	2.7	8.4	4.2	4.2
	Corn and cob meal,	5.6								
Hays, etc.,	Hay, mixed grasses,	6.0	.62	.29	5.34	12300	9.6	7.3	2.5	4.8
	Oat hay, - -	7.3								
Total food, - - -		**24.7**	**3.12**	**.84**	**10.84**	**29500**	**4.1**	**15.7**	**6.7**	**9.0**

RATIONS FED BY THIRTY-TWO CONNECTICUT DAIRYMEN IN FORTY-FIVE TESTS MADE BY THE STATION.

During the past five seasons forty-five rations found in actual use or proposed by the Station have been studied.

The experiments of the last four seasons—1893–94, 1894–95, 1895–96, and 1896–97—include thirteen cases in which comparative tests were made by feeding two different rations in succession to the same herd, in the manner described above, pages 17 and 18. In each case the ration actually being fed at the time was determined by weighing the feeding stuffs on the spot as they were fed and taking samples for analysis, and at the same time weighing the milk of each cow and determining the percentage of butter-fat. As soon as new rations could be calculated another ration was made with a larger proportion of protein, and a second test was made with this new ration, the fodder and milk being weighed and analyzed as before. In twelve of the cases the second ration was narrower than the first; in one instance the first ration was comparatively narrow, and the change was mainly from more to less expensive food materials. The length of each test was twelve days. The interval between the two tests of each comparative trial was from two to four weeks in the seven comparative experiments of 1893–94 and 1894–95, nine days in the two of 1895–96, and two weeks in 1896–97.

The results of these twenty-six comparative tests with thirteen herds are summarized in table 10 on page 63. The rations fed each herd in the different tests, the cost of the rations, the daily milk and butter product, and the cost of food to produce 100 pounds of milk and one pound of butter, are given in such a way that the results from the two rations can be easily compared. In the case of one herd (D) malt sprouts were fed in the second test and were not well eaten by most of the cows. In the case of herd G, the two rations were alike in the weights and proportions of nutrients. On this account the results with these two herds are omitted from the averages.

A brief discussion of these comparative tests and the conclusions reached will be found on page 61 and following.

In the following table are summarized the statistics of the forty-five rations studied. The table is for convenience divided into two parts. On the left hand pages of the table will be

found for each test the name of the dairyman, the number and average weight of the cows in the herd, and the actual ration fed. Following the principle set forth in the Report of this Station for 1896, pages 73 and 83, that cows should be fed in accordance with the milk flow rather than their live weight, the rations as actually fed are of more interest and value than when calculated over to a uniform basis of 1000 pounds live weight, as is frequently done.

On the right hand pages of the table are given the digestible nutrients and energy in the ration as calculated from the weights of the food materials and their percentage composition as found by analysis. The average daily milk flow, the average percentage of fat, and the average daily yield of butter per cow for each herd are also shown. The yields of butter were obtained in the case of each cow by adding one-sixth to the daily weight of fat in order to obtain the estimated yield of butter. More accurately, it is calculated that 96.3 per cent. of the butter-fat will be recovered in the butter, and that 82.4 per cent. of the weight of the butter is actual butter-fat. This is, however, very nearly equivalent to adding one-sixth to the weight of butter-fat as determined in the milk by the Babcock test.

The values given for the percentage of butter-fat are found by dividing the total amount of butter-fat obtained from the herd in one day by the total milk yield. This gives a slightly different but more accurate value than would be obtained by taking the average percentage of butter-fat as found by actual test of the milk yield of each cow.

TABLE 9.

Owners of herds and actual amounts of the different feeding stuffs fed per day on dairy farms in Connecticut.

Reference No. of Herd.	Number of Cows in Herd.	Avg. Weight of Herd.	OWNER OF HERD AND KINDS AND AMOUNTS OF FEEDS USED PER COW PER DAY. WEIGHTS IN POUNDS.	Weight of Feed.
		Lbs.	EXPERIMENTS OF WINTER OF 1892–93.	Lbs.
			W. S. Crane, Willimantic. Nov. 30–Dec. 2.	
1	13	900	Grain feeds:—Wheat bran, 2.5; linseed meal, 1.6; wheat middlings, 1.5; Buffalo gluten feed, 1.9,	7.5
			Coarse fodders:—Hay, 9.9; oat hay, 4.8; ensilage, 24.6,	39.3
			Total, - - - - - - - - -	46.8
			N. D. Potter, South Coventry. Dec. 5–9.	
2	18	875	Grain feeds:—Wheat middlings, 4.1; Chicago gluten meal, 3.2; ground oats, .9; corn meal, 1.8, -	10.0
			Coarse fodders:—Good hay, 6.3; poor hay, 1.9; ensilage, 48.4, - - - - - - -	56.6
			Total, - - - - - - - - -	66.6
			Samuel Stockwell, West Simsbury. Dec. 12–17.	
3	13	800	Grain feeds:—Cotton seed meal, 3.3; Buffalo gluten feed, 2.5; hominy meal, 2.8, - - - -	8.6
			Coarse fodders:—Hay, 8.8; stover, 7.4; potatoes, 6.1,	22.3
			Total, - - - - - - - - -	30.9
			C. P. Case, Simsbury. Dec. 19–24.	
4	19	800	Grain feeds:—Wheat bran, 3.0; cotton seed meal, 1.2; corn and cob meal, 4.3, - - - -	8.5
			Coarse fodders:—Hay, 17.1; stover, 7.3, - -	24.4
			Total, - - - - - - - - -	32.9
			Edward Manchester, West Winsted. Dec. 26–31.	
5	15	800	Grain feeds:—Wheat middlings, 1.8; Chicago gluten meal, 2.2; cotton seed meal, 2.6, - - -	6.6
			Coarse fodders:—Hay, 10.6; ensilage, 26.4, - -	37.0
			Total, - - - - - - - - -	43.6
			Isaac Barnes, Collinsville. Jan. 2–7.	
6	10	875	Grain feeds:—Corn meal, 3.2; wheat middlings, 1.8; cotton seed meal, 1.6, - - - - - -	6.6
			Coarse fodders:—Oat hay, 4.1; hay, 12.6; stover, 6.6,	23.3
			Total, - - - - - - - - -	29.9

TABLE 9.

Average amounts of digestible nutrients, with fuel values, in daily rations of dairy herds in Connecticut, with milk flow, butter-fat and estimated yields of butter.

Ref. No. of Herd.	FEEDING STUFFS.	DIGESTIBLE NUTRIENTS AND FUEL VALUE.					Milk Flow.	Percentage of Butter-fat.	Estimated Yield of Butter.
		Protein.	Fat.	Carbo-hydrates.	Fuel Value.	Nutritive Ratio.			
		Lbs.	Lbs.	Lbs.	Cal.	1:	Lbs.	%	Lbs.
1	Grain feeds, -	1.42	.50	3.16	10600	3.0	—	—	—
	Coarse fodder, -	.84	.40	8.76	19550	11.8	—	—	—
	Total, -	**2.26**	.90	11.92	**30150**	**6.2**	**16.8**	5.2	**1.02**
2	Grain feeds, -	1.79	.42	4.88	14150	3.3	—	—	—
	Coarse fodder, -	.65	.32	8.41	18200	14.0	—	—	—
	Total, -	**2.44**	.74	13.29	**32350**	**6.1**	**20.2**	4.9	**1.16**
3	Grain feeds, -	1.91	.70	3.72	13400	2.8	—	—	—
	Coarse fodder, -	.50	.22	8.10	16950	17.2	—	—	—
	Total, -	**2.41**	.92	11.82	**30350**	**5.8**	**18.3**	5.0	**1.08**
4	Grain feeds, -	1.18	.37	3.99	11150	4.1	—	—	—
	Coarse fodder, -	.[illegible]2	.37	9.34	20650	11.1	—	—	—
	Total, -	**2.10**	.74	13.33	**31800**	**7.1**	**14.9**	5.3	**.92**
5	Grain feeds, -	1.76	.61	2.11	9750	2.0	—	—	—
	Coarse fodder, -	.77	.39	10.04	21750	14.2	—	—	—
	Total, -	**2.53**	1.00	12.15	**31500**	**5.7**	**19.4**	4.0	**.90**
6	Grain feeds, -	1.08	.45	3.13	9750	3.9	—	—	—
	Coarse fodder, -	.70	.31	9.60	20450	14.7	—	—	—
	Total, -	**1.78**	.76	12.73	**30200**	**8.1**	**14.7**	4.5	**.77**

TABLE 9.—*(Continued.)*

Reference No. of Herd.	Number of Cows in Herd.	Avg. Weight of Herd.	Owner of Herd and Kinds and Amounts of Feed used per Cow per Day. Weights in Pounds.	Weight of Feed.
		Lbs.	EXPERIMENTS OF WINTER OF 1892–93.—*(Con.)*	Lbs.
			Elbert Manchester, Bristol. Jan. 9.–14.	
7	17	825	Grain feeds:—Ground oats, 2.3; corn meal, 4.7; wheat middlings, 4.6,	11.6
			Coarse fodders:—Hay,	20.1
			Total,	31.7
			Edward Norton, Farmington. Jan. 16–21.	
8	12	750	Grain feeds:—Wheat bran, 3.7; corn and cob meal, 5.5,	9.2
			Coarse fodders:—Hay,	21.5
			Total,	30.7
			H. W. Sadd, Wapping. Jan. 23–28.	
9	12	875	Grain feeds:—Corn meal, 1.8; wheat bran, 1.3; cotton seed meal, 1.3; cream gluten, 1.3,	5.7
			Coarse fodders:—Hay, 10.5; rowen, 4.5; stover, 4.5,	19.5
			Total,	25.2
			John Thompson, Broad Brook. Jan. 30–Feb. 4.	
10	18	850	Grain feeds:—Corn meal, 3.9; cotton seed meal, 2.0; wheat bran, 1.1,	7.0
			Coarse fodders:—Stover, 5.9; rowen, 8.7; hay, 4.4,	19.0
			Total,	26.0
			E. F. Thompson, Warehouse Point. Feb. 6–11.	
11	18	850	Grain feeds:—Wheat middlings, 2.6; corn meal, 2.6; cotton seed meal, 2.6; wheat bran, .7,	8.5
			Coarse fodders:—Hay, 10.3; oat hay, 5.7; stover, 3.2,	19.2
			Total,	27.7
			R. E. Holmes, West Winsted. Feb. 13–18.	
12	20	875	Grain feeds:—Wheat bran, 3.3; corn meal, 2.0; cotton seed meal, 2.1; malt sprouts, 4.0,	11.4
			Coarse fodders:—Ensilage, 36.0; hay, 6.5,	42.5
			Total,	53.9
			James B. Bliven, Baltic. Feb. 27–Mch. 4.	
13	19	800	Grain feeds:—Cotton seed meal, 1.3; wheat middlings, 5.1; corn meal, 2.6,	9.0
			Coarse fodders:—Ensilage, 24.6; hay, 6.0,	30.6
			Total,	39.6

TABLE 9.—*(Continued.)*

Reference No. of Herd.	Feeding Stuffs.	Digestible Nutrients and Fuel Value. Protein.	Fat.	Carbo-hydrates.	Fuel Value.	Nutritive Ratio.	Milk Flow.	Percentage of Butter-fat.	Estimated Yield of Butter.
		Lbs.	Lbs.	Lbs.	Cal.	1:	Lbs.	%	Lbs.
7	Grain feeds,	1.19	.54	6.35	16300	6.4	—	—	—
	Coarse fodder,	.82	.36	8.50	18850	11.3	—	—	—
	Total,	2.01	.90	14.85	35150	8.4	20.4	4.5	1.08
8	Grain feeds,	1.20	.38	4.01	11300	4.1	—	—	—
	Coarse fodder,	1.17	.32	8.70	19700	8.0	—	—	—
	Total,	2.37	.70	12.71	31000	6.0	17.6	4.7	.96
9	Grain feeds,	1.05	.51	2.75	9200	3.7	—	—	—
	Coarse fodder,	.84	.22	7.80	17000	9.9	—	—	—
	Total,	1.89	.73	10.55	26200	6.4	15.0	4.7	.83
10	Grain feeds,	.93	.42	3.16	9400	4.4	—	—	—
	Coarse fodder,	1.04	.29	7.92	17850	8.2	—	—	—
	Total,	1.97	.71	11.08	27250	6.4	20.7	4.6	1.12
11	Grain feeds,	1.62	.60	3.54	12100	3.0	—	—	—
	Coarse fodder,	.72	.26	7.90	17150	11.8	—	—	—
	Total,	2.34	.86	11.44	29250	5.7	15.6	4.9	.90
12	Grain feeds,	2.00	.49	4.23	13650	2.7	—	—	—
	Coarse fodder,	.61	.33	5.75	13200	10.7	—	—	—
	Total,	2.61	.82	9.98	26850	4.5	21.5	4.3	1.09
13	Grain feeds,	1.34	.51	4.22	12500	4.0	—	—	—
	Coarse fodder,	.42	.23	4.72	10500	12.5	—	—	—
	Total,	1.76	.74	8.94	23000	6.0	12.7	4.7	.69

TABLE 9.—*(Continued.)*

Reference No. of Herd.	Number of Cows in Herd.	Avg. Weight of Herd.	Owner of Herd and Kinds and Amounts of Feed used per Cow per Day. Weight in Pounds.	Weight of Feed.
		Lbs.	EXPERIMENTS OF WINTER OF 1892–93.—*(Con.)*	Lbs.
14	10	875	*G. W. Woodbridge, Manchester Green. Mch. 6–11.*	
			Grain feeds:—Cream gluten, 2.7; oat feed, 2.7; wheat bran, 2.7, - - - - - - - - -	8.1
			Coarse fodders:—Hay, 16.4; stover, 3.2, - - -	19.6
			Total, - - - - - - - -	27.7
15	19	850	*Harvey S. Ellis, Vernon Center. Mch. 13–18.*	
			Grain feeds:—Corn and cob meal, 4.9; rye meal, .9; wheat bran, .8; oat feed, .5; O. P. linseed meal, .5,	7.6
			Coarse fodders:—Hay, 10.3; stover, 7.2, - - -	17.5
			Total, - - - - - - - -	25.1
16	20	900	*Chas. P. Grosvenor, Abington. Mch. 20–25.*	
			Grain feeds:—Corn meal, 2.8; wheat bran, 1.5; Buffalo gluten feed, 1.9, - - - - - - -	6.2
			Coarse fodders:—Hay, 12.8; poor hay, 3.4; stover, 3.4,	19.6
			Total, - - - - - - - -	25.8
			EXPERIMENTS OF WINTER OF 1893–94.	
18	15	825	*W. S. Crane, Willimantic. Dec. 4–16.*	
			Grain feeds:—Wheat bran, 5.1; corn meal, 3.8; cotton seed meal, 1.2, - - - - - - - -	10.1
			Coarse fodders:—Corn ensilage, 10.0; hay, 16.6, -	26.6
			Total, - - - - - - - -	36.7
19	15	825	*Harvey S. Ellis, Vernon Center. Dec. 18–30.*	
			Grain feeds:—Corn and rye meal, 3.1; gluten meal, 2.7; bran, 3.0, - - - - - - - -	8.8
			Coarse fodders:—Corn stover, 9.8; meadow hay, 5.8,	15.6
			Total, - - - - - - - -	24.4
20	15	750	*Clifton Peck, Lebanon. Jan. 2–13.*	
			Grain feeds:—Cob meal, 6.2; wheat bran, 2.9, - -	9.1
			Coarse fodders:—Oat straw, 2.2; corn stover, 8.7; bog hay, 1.2; oat hay, 6.3, - - - - -	18.4
			Total, - - - - - - - -	27.5
21	15	825	*W. S. Crane, Willimantic. Jan. 15–27.*	
			Grain feeds:—Wheat bran, 5.4; corn meal, 2.7; cotton seed meal, 2.2, - - - - - - - -	10.3
			Coarse fodders:—Corn ensilage, 12.6; hay, 8.0; oat hay, 3.0, - - - - - - - -	23.6
			Total, - - - - - - - -	33.9

TABLE 9.—*(Continued.)*

Reference No. of Herd.	Feeding Stuffs.	Digestible Nutrients and Fuel Value. Protein.	Fat.	Carbo-hydrates.	Fuel Value.	Nutritive Ratio.	Milk Flow.	Percentage of Butter-fat.	Estimated Yield of Butter.
		Lbs.	Lbs.	Lbs.	Cal.	1:	Lbs.	%	Lbs.
14	Grain feeds, -	1.50	.56	3.32	11300	3.1	—	—	—
	Coarse fodder,	.83	.36	8.14	18200	10.8	—	—	—
	Total, -	2.33	.92	11.46	29500	5.8	18.5	4.8	1.04
15	Grain feeds, -	.60	.32	4.07	10050	8.0	—	—	—
	Coarse fodder,	.55	.16	7.82	16250	14.9	—	—	—
	Total, -	1.15	.48	11.89	26300	11.3	13.6	4.9	.78
16	Grain feeds, -	.55	.41	3.36	9000	7.8	—	—	—
	Coarse fodder,	.75	.31	8.03	17650	11.6	—	—	—
	Total, -	1.30	.72	11.39	26650	10.0	16.1	4.6	.87
18	Grain feeds, -	1.49	.45	4.63	13300	3.9	—	—	—
	Coarse fodder,	.66	.37	8.94	19450	15.0	—	—	—
	Total, -	2.15	.82	13.57	32750	7.3	18.8	5.0	1.10
19	Grain feeds, -	1.65	.56	3.84	12550	3.1	—	—	—
	Coarse fodder,	.58	.21	7.00	15000	12.9	—	—	—
	Total, -	2.23	.77	10.84	27550	5.6	17.3	5.1	1.03
20	Grain feeds, -	.92	.29	4.82	11850	6.1	—	—	—
	Coarse fodder,	.57	.19	6.50	13950	12.4	—	—	—
	Total, -	1.49	.48	11.32	25800	8.5	18.1	4.1	.86
21	Grain feeds, -	1.81	.49	4.25	13300	3.0	—	—	—
	Coarse fodder,	.58	.33	7.32	16100	13.9	—	—	—
	Total, -	2.39	.82	11.57	29400	5.7	18.9	4.9	1.08

TABLE 9.—*(Continued.)*

Reference No. of Herd.	Number of Cows in Herd.	Avg. Weight of Herd.	Owner of Herd and Kinds and Amounts of Feed used per Cow per Day. Weight in Pounds.	Weight of Feed.
		Lbs.	EXPERIMENTS OF WINTER OF 1893–94.—*(Con.)*	Lbs.
			C. H. Lathrop, North Franklin. Jan. 29–Feb. 10.	
22	12	725	Grain feeds:—Cob meal, 4.3; wheat bran, 3.0, - -	7.3
			Coarse fodders:—Stover, 3.5; oat hay, 3.9; hay, 4.5,	11.9
			Total, - - - - - - - -	19.2
			Clifton Peck, Lebanon. Feb. 12–24.	
23	15	750	Grain feeds:—Cob meal, 2.5; bran, 4.0; gluten meal, 2.3, - - - - - - - -	8.8
			Coarse fodders:—Oat straw, 1.8; corn stover, 7.3; bog hay, 1.2; oat hay, 6.9, - - - -	17.2
			Total, - - - - - - - -	26.0
			W. F. Maine, South Windham. Feb. 26–Mch. 3.	
24	14	775	Grain feeds:—Corn and cob meal, 5.7; Chicago gluten, 2.1; Imperial mixed bran, 2.8, - - - -	10.6
			Coarse fodders:—Stover, 2.6; clover hay, 6.4; hay, 6.7,	15.7
			Total, - - - - - - - -	26.3
			C. H. Lathrop, North Franklin. Mch. 5–17.	
25	12	725	Grain feeds:—Cotton seed meal, .4; linseed meal, .4; Chicago gluten, .4; cob meal, 4.0; wheat bran, 2.6,	7.8
			Coarse fodders:—Hay, 5.9; oat hay, 6.3, - - -	12.2
			Total, - - - - - - - -	20.0
			Chas. G. Nichols, West Willington. Mch. 19–24.	
26	15	800	Grain feeds:—Gluten meal, 2.8; middlings, 5.7, -	8.5
			Coarse fodders:—Hay, - - - - - - -	11.4
			Total, - - - - - - - -	19.9
			EXPERIMENTS OF WINTER OF 1894–95.	
			C. B. Davis, Yantic. Dec. 10–22.	
27	12	600	Grain feeds:—Corn meal, 4.6; wheat middlings, 4.6,	9.2
			Coarse fodders:—Stover, - - - - - -	12.7
			Total, - - - - - - - -	21.9
			W. F. Maine, South Windham. Dec. 24–Jan. 5.	
28	14	750	Grain feeds:—Imperial wheat feed, 3.6; corn and cob meal, 7.3, - - - - - - - -	10.9
			Coarse fodders:—Hay, 6.6; oat hay, 3.3; corn stover, 5.3, - - - - - - -	15.2
			Total, - - - - - - - -	26.1

TABLE 9.—*(Continued.)*

Reference No. of Herd.	FEEDING STUFFS.	DIGESTIBLE NUTRIENTS AND FUEL VALUE.					Milk Flow.	Percentage of Butter-fat.	Estimated Yield of Butter.
		Protein.	Fat.	Carbo-hydrates.	Fuel Value.	Nutritive Ratio.			
		Lbs.	Lbs.	Lbs.	Cal.	1:	Lbs.	%	Lbs.
22	Grain feeds, -	.77	.21	3.66	9150	5.4	—	—	—
	Coarse fodder,	.61	.20	5.41	12000	9.6	—	—	—
	Total, -	1.38	.41	9.07	21150	7.3	15.1	4.0	.70
23	Grain feeds, -	1.46	.32	4.04	11550	3.3	—	—	—
	Coarse fodder,	.54	.18	6.12	13150	12.2	—	—	—
	Total, -	2.00	.50	10.16	24700	5.7	17.9	4.3	.89
24	Grain feeds, -	1.53	.40	5.07	13950	3.9	—	—	—
	Coarse fodder,	1.17	.24	6.42	15150	5.9	—	—	—
	Total, -	2.70	.64	11.49	29100	4.8	19.9	4.4	1.03
25	Grain feeds, -	1.16	.29	3.67	10200	3.8	—	—	—
	Coarse fodder,	.64	.22	5.42	12200	9.4	—	—	—
	Total, -	1.80	.51	9.09	22400	5.7	15.9	4.3	.79
26	Grain feeds, -	1.55	.66	3.33	11900	3.1	—	—	—
	Coarse fodder,	.45	.18	5.05	11000	11.8	—	—	—
	Total, -	2.00	.84	8.38	22900	5.1	13.2	5.0	.77
27	Grain feeds, -	.99	.34	4.89	12400	5.7	—	—	—
	Coarse fodder,	.30	.11	4.51	9400	15.8	—	—	—
	Total, -	1.29	.45	9.40	21800	8.0	14.0	4.6	.76
28	Grain feeds, -	1.06	.37	6.09	14800	6.5	—	—	—
	Coarse fodder,	.57	.24	7.60	15850	14.1	—	—	—
	Total, -	1.63	.61	13.69	30650	9.2	17.9	4.7	.93

TABLE 9.—*(Continued.)*

Reference No. of Herd.	Number of Cows in Herd.	Avg. Weight of Herd.	Owner of Herd and Kinds and Amounts of Feed used per Cow per Day. Weight in Pounds.	Weight of Feed.
		Lbs.	EXPERIMENTS OF WINTER OF 1894–95.—*(Con.)*	Lbs.
29	12	600	*C. B. Davis, Yantic. Jan. 7–19.*	
			Grain feeds:—Wheat middlings, 5.9; malt sprouts, 3.5; corn meal, 3.0,	12.4
			Coarse fodders:—Stover,	9.7
			Total,	22.1
30	14	750	*W. F. Maine, South Windham. Jan. 21–Feb. 2.*	
			Grain feeds:—Imperial wheat feed, 3.0; O. P. linseed meal, 3.0; corn and cob meal, 2.9,	8.9
			Coarse fodders:—Hay, 3.3; oat hay, 5.2; corn stover, 4.8,	13.3
			Total,	22.2
31	10	800	*I. W. Trowbridge, Putnam. Feb. 4–16.*	
			Grain feeds:—Wheat middlings, 4.5; corn and cob meal, 2.2,	6.7
			Coarse fodders:—Corn ensilage, 34.9; oat hay, 2.9; corn stover, 2.9; bog hay, 3.5,	44.2
			Total,	50.9
32	14	775	*R. L. Sadd, Wapping. Feb. 18–Mch. 2.*	
			Grain feeds:—Buffalo gluten feed, 5.2; wheat bran, 2.9,	8.1
			Coarse fodders:—Hay, 7.7; corn stover, 3.2; corn fodder, 3.3,	14.2
			Total,	22.3
33	10	800	*I. W. Trowbridge, Putnam. Mch. 4–16.*	
			Grain feeds:—Wheat middlings, 3.9; cotton seed meal, 2.0; corn and cob meal, 2.9,	7.9
			Coarse fodders:—Clover hay, 10.0; oat hay, 1.9; corn stover, 1.9; bog hay, 1.9,	15.7
			Total,	23.6
34	14	775	*R. L. Sadd, Wapping. Mch. 18–30.*	
			Grain feeds:—Wheat bran, 4.0; cotton seed meal, 1.9; Buffalo gluten feed, 2.0,	7.9
			Coarse fodders:—Corn stover, 2.9; Hungarian hay, 5.3; corn fodder, 5.8,	15.8
			Total,	23.7

TABLE 9.—(*Continued.*)

Reference No. of Herd.	Feeding Stuffs.	Digestible Nutrients and Fuel Value. Protein.	Fat.	Carbo-hydrates.	Fuel Value.	Nutritive Ratio.	Milk Flow.	Percentage of Butter-fat.	Estimated Yield of Butter.
		Lbs.	Lbs.	Lbs.	Cal.	1:	Lbs.	%	Lbs.
29	Grain feeds, -	1.78	.41	5.52	15350	3.6	—	—	—
	Coarse fodder,	.31	.11	4.85	10000	16.6	—	—	—
	Total, -	2.09	.52	10.37	25350	5.5	13.7	4.6	.74
30	Grain feeds, -	1.25	.26	4.26	11350	3.9	—	—	—
	Coarse fodder,	.56	.18	6.32	13600	12.1	—	—	—
	Total, -	1.81	.44	10.58	24950	6.4	18.3	4.8	1.03
31	Grain feeds, -	.72	.23	3.14	8200	5.1	—	—	—
	Coarse fodder,	.60	.42	7.72	17250	14.4	—	—	—
	Total, -	1.32	.65	10.86	25450	9.3	17.8	4.7	.97
32	Grain feeds, -	1.69	.83	3.24	12700	3.0	—	—	—
	Coarse fodder,	.45	.22	6.59	14000	15.8	—	—	—
	Total, -	2.14	1.05	9.83	26700	5.7	17.7	4.6	.95
33	Grain feeds, -	1.14	.44	3.99	11400	4.4	—	—	—
	Coarse fodder,	1.09	.31	6.51	15450	6.6	—	—	—
	Total, -	2.23	.75	10.50	26850	5.5	18.5	4.7	1.01
34	Grain feeds, -	1.59	.63	3.05	11300	2.8	—	—	—
	Coarse fodder,	.57	.22	6.94	14900	13.0	—	—	—
	Total, -	2.16	.85	9.99	26200	5.5	15.4	4.8	.87

TABLE 9.—*(Continued.)*

Reference No. of Herd.	Number of Cows in Herd.	Avg. Weight of Herd.	Owner of Herd and Kinds and Amounts of Feed used per Cow per Day. Weight in Pounds.	Weight of Feed.
		Lbs.	EXPERIMENTS OF WINTER OF 1895–96.	Lbs.
35	11	775	*Simon Brewster, Jewett City. Dec. 3–14.*	
			Grain feeds:—Corn meal, 3.2; wheat bran, 1.7; wheat middlings, 2.4, - - - - - - - -	7.3
			Coarse fodders:—Oat hay, 6.8; corn stover, 10.9, -	17.7
			Total, - - - - - - - -	25.0
36	14	750	*H. R. Hayden, East Hartford. Feb. 11–22.*	
			Grain feeds:—Wheat bran, 3.7; linseed meal, 1.6; corn meal, 1.6; Buffalo gluten feed, 2.5, - -	9.4
			Coarse fodders:—Hay, 1st quality, 5.0; hay, 2d quality, 5.0; stover, 7.1; potatoes, 2.0, - - - -	19.1
			Total, - - - - - - - -	28.5
37	11	775	*Simon Brewster, Jewett City. Dec. 22–Jan. 2.*	
			Grain feeds:—Gluten meal, 3.1; wheat bran, 1.5; wheat middlings, 2.2, - - - - -	6.8
			Coarse fodders:—Clover hay, 6.4; corn stover, 9.2, -	15.6
			Total, - - - - - - - -	22.4
38	14	750	*H. R. Hayden, East Hartford. Mch. 6–17.*	
			Grain feeds:—Wheat bran, 4.1; linseed meal, 1.0; corn meal, 1.0; Buffalo gluten feed, 2.0; cotton seed meal, 2.1, - - - - - - - -	10.2
			Coarse fodders:—Hay, 1st quality, 4.0; hay, 2d quality, 4.0; stover, 6.7; potatoes, 2.0, - - - -	16.7
			Total, - - - - - - - -	26.9
			EXPERIMENTS OF WINTER OF 1896–97.	
39	13	725	*S. Wolcott Bissell, East Windsor. Dec. 14–26.*	
			Grain feeds:—Corn meal, 3.2; Buffalo gluten feed, 4.1,	7.3
			Coarse fodders:—Corn ensilage, 28.4; oat hay, 6.3; hay, 3.4; potatoes, 8.3, - - - - -	46.4
			Total, - - - - - - - -	53.7
40	9	750	*H. H. McKnight, Ellington. Dec. 28–Jan. 9.*	
			Grain feeds:—Corn meal, 3.1; wheat bran, 1.2; ground oats, .2; rye meal, .1; cotton seed meal, 1.9, -	6.5
			Coarse fodders:—Corn ensilage, 29.4; corn stover, 6.6; hay, mixed grasses, 4.3, - - - -	40.3
			Total, - - - - - - - -	46.8

TABLE 9.—*(Continued.)*

Reference No. of Herd.	Feeding Stuffs.	Digestible Nutrients and Fuel Value. Protein.	Fat.	Carbo-hydrates.	Fuel Value.	Nutritive Ratio.	Milk Flow.	Percentage of Butter-fat.	Estimated Yield of Butter.
		Lbs.	Lbs.	Lbs.	Cal.	1:	Lbs.	%	Lbs.
35	Grain feeds, -	.78	.29	3.98	10050	5.9	—	—	—
	Coarse fodder,	.64	.27	7.63	16550	12.8	—	—	—
	Total, -	1.42	.56	11.61	26600	9.0	16.7	4.3	.84
36	Grain feeds, -	1.77	.40	4.38	13150	3.0	—	—	—
	Coarse fodder,	.57	.13	7.58	15700	13.7	—	—	—
	Total, -	2.34	.53	11.96	28850	5.6	17.0	5.1	1.02
37	Grain feeds, -	1.39	.33	3.15	9850	2.8	—	—	—
	Coarse fodder,	.88	.16	6.94	15200	8.2	—	—	—
	Total, -	2.27	.49	10.09	25050	4.9	17.4	4.4	.90
38	Grain feeds, -	2.25	.61	4.09	14400	2.4	—	—	—
	Coarse fodder,	.49	.11	6.57	13550	13.8	—	—	—
	Total, -	2.74	.72	10.66	27950	4.5	17.4	5.4	1.10
39	Grain feeds, -	1.11	.23	3.94	10350	4.0	—	—	—
	Coarse fodder,	.70	.35	9.31	20100	14.4	—	—	—
	Total, -	1.81	.58	13.25	30450	8.0	17.1	4.3	.86
40	Grain feeds, -	1.13	.45	2.93	9450	3.5	—	—	—
	Coarse fodder,	.63	.39	10.02	21450	17.3	—	—	—
	Total, -	1.76	.84	12.95	30900	8.4	16.9	5.2	1.02

TABLE 9.—*(Continued.)*

Reference No. of Herd.	Number of Cows in Herd.	Avg. Weight of Herd.	Owner of Herd and Kinds and Amounts of Feed used per Cow per Day. Weight in Pounds.	Weight of Feed.
		Lbs.	EXPERIMENTS OF WINTER OF 1896–97.—*(Con.)*	Lbs.
			S. Wolcott Bissell, East Windsor. Jan. 11–23.	
			Grain feeds:—Buffalo gluten feed, 3.7; wheat bran, 2.7; cotton seed meal, 1.8,	8.2
41	13	725	Coarse fodders:—Corn ensilage, 28.4; oat hay, 4.1; hay, 2.8,	35.3
			Total,	43.5
			H. H. McKnight, Ellington. Jan. 25–Feb. 6.	
			Grain feeds:—Wheat bran, 3.7; corn meal, 1.2; Chic. gluten meal, 1.2; cotton seed meal, 2.2,	8.3
42	9	750	Coarse fodders:—Corn ensilage, 28.9; corn stover, 5.7; hay, mixed grasses, 3.1,	37.7
			Total,	46.0
			Wm. H. Hammond, Elliot. Feb. 8–20.	
			Grain feeds:—Fine wheat feed, 4.2; Rockford gluten feed, 4.2; corn and cob meal, 1.0; corn meal, 1.0; O. P. linseed meal, 1.0,	11.4
43	9	775	Coarse fodders:—Corn stover, 6.0; oat straw, 4.2; turnips, 4.2,	14.4
			Total,	25.8
			Everett A. Elliot, Elliot. Feb. 22–Mch. 6.	
			Grain feeds:—Buffalo gluten feed, 4.9; corn and cob meal, 6.9,	11.8
44	8	725	Coarse fodders:—Hay, mixed grasses, 7.3; oat hay, 6.3; bog hay, 1.4,	15.0
			Total,	26.8
			Wm. H. Hammond, Elliot. Mch. 8–20.	
			Grain feeds:—Wheat bran, 2.0; wheat middlings, 2.0; Chicago gluten meal, 4.7; Rockford gluten feed, 1.0; O. P. linseed meal, 1.7,	11.4
45	9	775	Coarse fodders:—Oat straw, 4.4; corn stover, 7.2,	11.6
			Total,	23.0
			Everett A. Elliot, Elliot. Mch. 22–Apr. 1.	
			Grain feeds:—Chicago gluten meal, 5.8; corn and cob meal, 5.6,	11.4
46	8	725	Coarse fodders:—Hay, mixed grasses, 6.0; oat hay, 7.3,	13.3
			Total,	24.7

TABLE 9.—(*Continued.*)

Reference No. of Herd.	Feeding Stuffs.	Digestible Nutrients and Fuel Value. Protein.	Fat.	Carbo-hydrates.	Fuel Value.	Nutritive Ratio.	Milk Flow.	Percentage of Butter-fat.	Estimated Yield of Butter.
		Lbs.	Lbs.	Lbs.	Cal.	1:	Lbs.	%	Lbs.
41	Grain feeds, -	1.85	.38	2.92	10500	2.1	—	—	—
	Coarse fodder,	.59	.35	7.83	17100	14.5	—	—	—
	Total, -	2.44	.73	10.75	27600	5.1	16.6	4.7	.91
42	Grain feeds, -	1.79	.57	3.18	11650	2.5	—	—	—
	Coarse fodder,	.52	.31	7.56	16350	16.0	—	—	—
	Total, -	2.31	.88	10.74	28000	5.5	17.0	5.5	1.10
43	Grain feeds, -	1.84	.51	5.87	16500	3.8	—	—	—
	Coarse fodder,	.27	.11	4.28	8900	16.7	—	—	—
	Total, -	2.11	.62	10.15	25400	5.5	22.1	5.0	1.29
44	Grain feeds, -	1.57	.67	6.15	17200	4.9	—	—	—
	Coarse fodder,	.55	.24	5.88	12950	11.7	—	—	—
	Total, -	2.12	.91	12.03	30150	6.6	22.8	4.7	1.26
45	Grain feeds, -	2.98	.63	4.47	16500	2.0	—	—	—
	Coarse fodder,	.28	.10	4.63	9550	17.4	—	—	—
	Total, -	3.26	.73	9.10	26050	3.3	23.4	4.9	1.33
46	Grain feeds, -	2.50	.55	5.50	17200	2.7	—	—	—
	Coarse fodder,	.62	.29	5.34	12300	9.6	—	—	—
	Total, -	3.12	.84	10.84	29500	4.1	21.4	5.1	1.27

RECAPITULATION OF RATIONS FED AND YIELDS OF MILK AND BUTTER IN THE TESTS OF CONNECTICUT DAIRY HERDS DURING FIVE SEASONS.

As the study of dairy rations and the coöperative experiments in feeding dairy herds which were begun by this Station in 1892 have now covered a period of five years, a general summary of the results seems proper in this place.

The coöperative experiments have included forty-five tests with thirty-two different herds. Thirteen of the herds were used for two tests each. The total number of cows was 453. The breeds and grades were as follows:

Breeds and grades, and number of cows in each division of the thirty-two herds studied.

Ayrshire.		Devon.		Durham or Shorthorn.		Guernsey.		Holstein.		Jersey.		Swiss.		Native.	Total.
R.	G.	R.	G.	R.	G.	R.	G.	R.	G.	R.	G.	R.	G.		
2	6	1	11	1	5	26	23	3	19	37	259	3	2	55	453

R.=Registered. G.=Grade.

The forty-five rations in the same number of tests included thirty-two which were found in actual use by some of the more intelligent and successful dairymen in the State, and thirteen rations which were proposed by the Station to test the effect of larger amounts of protein than those used by the feeders. These thirteen tests with the narrower rations were made after the studies of the actual feeding practice in the same number of cases. The number of cows in each herd (*i. e.*, in the lot used for the test) ranged from eight to twenty and averaged fourteen. The average estimated live weight per cow of the several herds ranged from 600 to 900 pounds, and the average of all the herds was 800 pounds per cow.

The forty-five rations as fed contained from 1.15 to 3.26 pounds of digestible protein, averaging 2.1 pounds, and the fuel values ranged from 21,150 to 35,150 calories, averaging 27,750 calories. The nutritive ratios ranged from 1:3.3 to 1:11.3, with an average of 1:6.5.

Thirteen of these forty-five rations were proposed by the Station, so that thirty-two rations represent the feeding practice as actually found in operation in this State.

In the thirty-two tests of actual feeding practice the average ration per cow per day supplied from 1.15 to 2.70 pounds, averaging 2.0 pounds, of digestible protein; while the range of fuel values was from 21,150 to 35,150, averaging 28,250 calories. The nutritive ratios of these rations ranged from 1:4.5 to 1:11.3, averaging 1:7.0.

To illustrate the apparent effects of larger and smaller quantities of protein these thirty-two tests have been divided into two groups. The first group includes all herds receiving two pounds or less of digestible protein per cow per day; the second group, those receiving more than two pounds of digestible protein. In the first group of sixteen tests, including sixteen herds and 226 cows, the digestible protein per cow per day ranged from 1.3 pounds to 2.0 pounds, with an average of 1.62 pounds. The nutritive ratios ranged from 1:6.0 to 1:11.3, with an average of 1:8.1. In the second group (including sixteen herds and 227 cows) the digestible protein ranged from 2.1 to 2.7 pounds per cow per day, with an average of 2.32 pounds. The nutritive ratios ranged from 1:4.5 to 1:7.3, averaging 1:5.9. All but one of the first group were very wide, while most of the second group might be regarded as moderately narrow, ten out of sixteen being below 1:6.0. The results obtained with these two groups are easily compared with each other in respect to feeding, milk production, and profit, as shown in the table on the page following.

In thirteen of the thirty-two cases just mentioned the tests were repeated with new rations containing an increase of protein. The number of cows in the thirteen herds ranged from eight to fifteen, the whole number being 156. The second test with each herd included the same cows as were used in the first test. These second tests, with the larger amounts of protein and the narrower nutritive ratios, were made from two to four weeks later than the first test with the wide ration. Owing to advance in the period of lactation the milk flow and amount of butter-fat would naturally be less than in the first tests. Only eleven of these comparative tests are included in the following discussion for reasons explained on page 42.

The thirteen comparative tests with narrow rations were made with the same herds as the thirteen tests with the wider ration.

Averages of rations fed by Connecticut dairymen, with daily yields of milk and butter and percentages of fat.

Rations.	Digestible Nutrients and Fuel Values.					Daily Milk.	Average Fat.	Daily Butter.
	Protein.	Fat.	Carbo-hydrates.	Fuel Value.	Nutritive Ratio.			
	Lbs.	Lbs.	Lbs.	Cal.	1:	Lbs.	%	Lbs.
Average of all the rations (45),	2.08	.72	11.21	27750	6.5	17.6	4.8	.97
Average of 32 rations found in actual practice, - -	1.97	.73	11.57	28250	7.0	17.5	4.8	.96
Average of rations containing 2.0 pounds or less of digestible protein per day, as fed 16 herds (226 cows) in actual practice, - -	1.62	.65	11.37	26900	8.1	16.3	4.7	.87
Average of rations containing more than 2.0 pounds of digestible protein per day, as fed 16 herds (227 cows) in actual practice, - -	2.32	.81	11.77	29600	5.9	18.7	4.9	1.05
Average of 11 wide rations (first test) as found in use,	1.78	.64	11.86	28100	7.7	18.0	4.7	1.00
Average of 11 narrower rations (second test) proposed by the Statton, -	2.40	.67	10.37	26600	5.1	18.2	4.9	1.04

MILK AND BUTTER PRODUCT OBTAINED IN THE FORTY-FIVE TESTS OF DAIRY HERDS.

In the forty-five tests with the same number of rations there was considerable variation in the quantity of product obtained. The wide variations in milk and butter product were doubtless due in part to the quality of the cows making up the herds, and in part to differences in the rations fed. The yields of milk for the 45 separate tests (32 distinct herds) ranged from 13.2 pounds to 23.4 pounds per day, while the average yields of butter ranged from .7 pounds to 1.33 pounds per day, or from very nearly 5 pounds to 9⅓ pounds of butter per week. This means that, taking the average per cow, the herd giving the largest flow of milk produced 80 per cent. more than the one giving the smallest flow, while the herd producing the most butter gave 90 per cent. more than the one producing the smallest amount.

The advantage of rations with liberal quantities of protein is quite clearly shown when the herds are divided into two groups

according to the amounts of protein in the rations fed. (See table, page 60.) The group composed of those herds receiving two pounds or less of digestible protein per cow per day produced on the average 16.3 pounds of milk and .87 pounds of butter per day, while the group receiving more than two pounds of digestible protein per cow per day averaged 18.7 pounds of milk and 1.05 pounds of butter. This means that the herds which were fed the larger quantities of protein produced on the average 15 per cent. more milk and 20 per cent. more butter per cow than those fed the smaller quantities of protein.

Consideration must be given to the fact that these are not comparative tests of the same lot of cows with different rations. It is, however, a striking illustration of results obtained in actual practice with rations varying quite widely in the amount of protein. The two groups of tests contained the same number of herds (sixteen), and practically the same number of cows (one group had 227 and the other 226). While the breeds and general quality* of the two groups have not been compared closely, yet the statistics taken show that a large majority of the cows of both groups were of the same general class, that is, they were mainly Jerseys and Guernseys and their grades.

It is impracticable to compare accurately the costs of the rations fed throughout these 32 tests, but the general results of our experiments indicate that the rations with relatively large proportions of protein are cheaper than those containing relatively smaller quantities.* In the 13 studies of two tests each on the same herds, the average cost of the rations high in protein was one cent per day less than those lower in protein. In the 16 herds fed more than two pounds of digestible protein per cow per day the average increase of .18 pounds in the daily butter yield has a value, at 20 cents per pound, of 3.6 cents. It would not be fair to claim that this increase is due wholly to the better class of rations fed, but there is evidence that the rations used had considerable to do with the final results.

THE EFFECT OF NARROW AND WIDE RATIONS ON MILK AND BUTTER YIELD.

During the past four winters thirteen of the dairy herds studied were fed in the first test a ration made up by the

* See reference to this in the following article.

dairyman, and in the second test a ration proposed by the Station. The rations fed in the first test were usually rather wide, that is, they contained relatively small quantities of protein. The chief change made by the ration proposed by the Station was to increase the amount and proportion of protein over that fed in the first test. It will be seen that in the majority of cases the yields of milk and of butter-fat were larger and the profit was greater with the second or narrower ration. In eight cases out of thirteen the estimated cost of the second or narrow ration was less than of the first or wide ration; in two instances the cost was essentially the same in each, while in the other three instances the cost of the second ration was slightly increased. In eight cases the cost of producing a hundred pounds of milk and in ten cases the cost of producing one pound of butter was less when the herd was fed on the second or narrow ration.

The above statements refer to the total cost of the rations, and do not take into consideration the value of the manure obtainable in the different instances. The net cost to the farmer takes into account the value of the manure, and is the total cost less the value of that portion of fertilizing material in the feeding stuffs which can be saved in the manure. When the manurial value is taken into consideration, the net cost of the rations and the net cost of producing a hundred pounds of milk and one pound of butter was as cheap or cheaper in all cases except one, when the narrow rations were fed.

One point to be especially noticed is that the tests with the narrower rations were made considerably later than those with the wider ration. Although a shrinkage in production naturally comes with advance in the period of lactation, and although the second test was made from one to four weeks after the close of the first test, the herds as a whole more than held their own when changed from the wider rations to narrower rations. In many cases there was a slight increase in the percentage of fat in the second test over that found in the first test. With some of the herds this was sufficient to cause an appreciable increase in the yield of butter-fat, even though the yield of milk remained the same or was even less.

TABLE 10.

Summary of daily rations fed, and daily milk and butter yield from thirteen herds with a wide as compared with a narrower ration.

Herd.		Average Weight of Cows.	No. of Test.	Daily Ration per Head. Digestible Protein.	Fuel Value of Digestible Nutrients.	Nutritive Ratio.	Total Cost.	Net Cost.*	Average Daily Milk Flow.	Yield of Butter.†	Cost of Food to Produce 100 lbs. Milk. Total Cost.	Net Cost.*	1 lb. Butter. Total Cost.	Net Cost.*
		Lbs.		Lbs.	Cal.	1:	Cts.	Cts.	Lbs.	Lbs.	$	Ct	Ct	Ct
A	Wide ration,	825	18	2.15	32750	7.3	26.6	14.3	18.1	1.10	1.47	79	24	13
	Nar. ration,		21	2.39	29400	5.7	21.7	9.8	18.9	1.12	1.15	52	19	9
B	Wide ration,	750	20	1.49	25800	8.5	18.6	9.5	18.1	.90	1.00	53	21	11
	Nar. ration,		23	2.01	24700	5.7	18.3	9.0	17.9	.92	1.03	50	20	10
C	Wide ration,	725	22	1.38	21150	7.3	19.4	12.5	13.7	.67	1.41	91	29	19
	Nar. ration,		25	1.80	22400	5.7	17.8	9.9	13.6	.71	1.30	73	25	14
D‡	Wide ration,	600	27	1.29	21800	8.0	14.1	7.0	14.0	.79	1.01	50	18	9
	Nar. ration,		29	2.09	25350	5.5	15.1	6.9	13.7	.76	1.10	50	20	9
E	Wide ration,	750	28	1.63	30650	9.2	18.4	10.5	17.9	1.02	1.03	59	18	10
	Nar. ration,		30	1.81	24950	6.4	15.9	7.1	18.3	1.07	.87	39	15	7
F	Wide ration,	800	31	1.32	25450	9.3	15.1	6.8	17.8	1.01	.85	38	15	7
	Nar. ration,		33	2.23	26850	5.5	18.0	7.0	18.5	1.04	.97	38	17	7
G‡	1st ration,	775	32	2.14	26750	5.7	16.7	7.6	17.7	.98	.94	43	17	8
	2d ration,		34	2.16	26200	5.5	16.2	5.6	15.4	.90	1.05	36	18	6
H	Wide ration,	775	35	1.42	26600	9.0	17.3	7.0	16.7	.84	1.04	42	21	8
	Nar. ration,		37	2.27	25050	4.9	17.4	5.1	17.4	.90	1.00	29	19	6
I	1st ration,	750	36	2.34	28850	5.6	23.0	8.9	17.0	1.02	1.35	52	23	9
	2d ration,		38	2.74	27950	4.5	21.7	7.6	17.4	1.10	1.25	44	20	7
J	Wide ration,	725	39	1.81	30450	8.0	16.3	10.5	17.1	.86	.95	61	19	12
	Nar. ration,		41	2.44	27600	5.1	14.6	8.3	16.6	.91	.88	50	16	9
K	Wide ration,	750	40	1.76	30900	8.4	15.6	10.0	16.9	1.02	.92	59	15	10
	Nar. ration,		42	2.31	28000	5.5	14.9	8.4	17.0	1.10	.88	49	14	8
L	1st ration,	775	43	2.15	26550	5.5	13.2	7.7	22.1	1.29	.60	35	10	6
	2d ration,		45	3.26	26050	3.3	13.8	6.7	23.4	1.33	.59	29	10	5
M	Wide ration,	725	44	2.12	30150	6.6	15.9	10.3	22.8	1.26	.70	45	13	8
	Nar. ration,		46	3.12	29500	4.1	15.7	9.0	21.4	1.27	.73	42	12	7
Average 11 tests with wide rations,‡ - -		765	–	1.78	28100	7.7	18.1	9.9	18.0	1.00	1.03	56	19	10
Average 11 tests with narrower rations,‡ -		765	–	2.40	26600	5.1	17.2	8.1	18.2	1.04	.97	45	17	8

* Total cost of food less value of obtainable manure.

† Assuming butter to contain 82.4 per cent. butter-fat and 96.3 per cent. of the fat in the whole milk to be saved in the butter.

‡ Results with D and G omitted from averages. (See page 42.)

SUMMARY.—THE EXPERIMENTS AND RESULTS.

In the winter of 1892–93 the Station began making systematic observations of the winter feeding practices of Connecticut dairymen. The chief points upon which information was obtained were: Number of animals in the herd; breed, age, and approximate weight of each cow; length of time since dropping last calf and till due to calve again; kinds, weights, and chemical composition of feeding stuffs used; weights of milk flow; percentages and amounts of butter-fat in the milk.

The following is a nearly complete list of the kinds of feeding stuffs used. The nutritive ratios are calculated from the analyses made in the experiments, together with other analyses of like materials, as used in New England. The more nitrogenous materials are, of course, those richest in protein or "flesh formers," while the more carbonaceous are those poorer in protein and having larger proportions of the fuel ingredients, i. e., fats, and especially the carbohydrates. The former, with smaller nutritive ratios, tend to make narrow rations, while the latter make wide rations. The latter were used in much larger proportions than the former.

CLASSIFICATION OF FEEDING STUFFS USED IN THESE TESTS.

Nitrogenous Feeding Stuffs—Rich in Protein.	Nutritive Ratio.	Carbonaceous Feeding Stuffs—Poor in Protein.	Nutritive Ratio.
Cotton seed meal, - -	1:1.4	Turnips, - - -	1:7.0
Chicago gluten meal, -	1:1.8	Rye meal, - - -	1:7.3
O. P. linseed meal, - -	1:1.9	Corn ensilage, - -	1:8.0
Buffalo gluten feed, - -	1:2.5	Potatoes, - - -	1:8.1
Rockford gluten feed, -	1:3.4	Corn and cob meal, -	1:8.8
Fine wheat feed, - -	1:3.7	Corn meal, - - -	1:9.4
Wheat bran, - - -	1:4.6	Bog hay, - - -	1:10.2
Wheat middlings, - -	1:4.8	Oat hay, - - -	1:10.6
Ground oats, - - -	1:5.9	Hay, mixed grasses, -	1:11.4
		Corn stover, - - -	1:15.3
		Oat straw, - - -	1:25.5

In 1892–93 sixteen herds were visited and a five-days' test was made with each. In 1893–94 six herds were visited, and in four instances the time of study of the feeding, management, and products of each herd was extended to twelve days. As soon as the analyses could be made, the amounts of actual nutrients in the rations fed were calculated, and in three cases other rations were

suggested. The feed was gradually changed to the suggested ration with these three herds, and after four weeks from the close of the first test another twelve-days' test was made with the new ration.

In 1894–95 four herds were studied on the same plan as in the longer studies made the previous winter, except that the length of time between the two tests, on the same herd, was shortened to two weeks.

In 1895–96 two herds were studied on the same plan as those of the previous winter, except that the time between tests was reduced to nine days. In one of these cases the herd was fed a very large ration of protein with an unusually narrow nutritive ratio.

In 1896–97 four herds were studied on the same general plan as those of the three previous winters, and the time between the tests was two weeks. In one of these cases, however, the herd was fed in accordance with the milk flow. The average ration was very heavy in protein, and had an unusually narrow nutritive ratio.

GENERAL DEDUCTIONS AND CONCLUSIONS.

(1.) In these forty-five tests on thirty-two distinct herds the cost of producing milk and butter depended largely upon the kind of cows and their condition as regards time from calving, and the kind of ration fed. Many of the individual cows in the tests were not returning the cost of feed. The average yield of milk for the forty-five separate tests ranged from 13.2 pounds to 23.4 pounds per day, while the average yield of butter ranged from seven-tenths of a pound to 1.33 pounds per day. This means that the herd giving the largest flow of milk was producing 80 per cent. more than the one giving the smallest flow, while the herd producing the most butter was giving 90 per cent. more than the one giving the smallest yield of butter. Cows calving in the fall are most profitable for general dairying, as the price of butter is about 40 per cent. higher during the winter months than during the summer months. One of the first things our dairymen need to do is to make a closer study of the individual animals of their herds, and to reject the unprofitable ones.

(2.) In these tests the cost of the rations depended largely upon the proportion of the cheaper coarse fodders like corn silage, corn

stover, clover hay, oat hay, and second quality mixed hay which went to make up the total coarse fodders of the ration. The better grades of hay, such as timothy and red-top were among the most expensive feeding stuffs used. When good hay sells at fourteen to eighteen dollars per ton it is generally more profitable to sell than to feed to dairy cows.

(3.) A liberal proportion of the nitrogenous grain feeds tended to lessen the cost of the ration in the majority of cases, while the net cost was greatly reduced by their use. The nitrogenous feeding stuffs like rowen hay, clovers, oats and peas, cotton seed, linseed, and gluten meals, should be more largely used in feeding dairy stock.

(4.) The legumes, such as clovers, peas, soy beans, etc., should be more largely grown and more largely used in making up feeding rations. The larger the proportion of these nitrogenous coarse fodders used in the ration, the less will be the quantity of the concentrated nitrogenous grain feeds which need to be purchased and used.

*(5.) While it is impossible to suggest any formula for feeding that it would be wise to follow rigidly under the widely varying conditions existing on our dairy farms, yet it is better to be guided by some general formula or standard than to have no rule for guidance. Our studies tend to point more and more to the conclusion that rations should be compounded in accordance with the milk flow rather than in accordance with the live weight of the animals. If the milk flow is uniform, the feed need not vary much for variations of 100 to 200 pounds live weight, but with an increase in the milk flow the size of the ration should be larger, and especially the protein should be increased both in total quantity and relatively, in order to meet the increased demands on the system of the animal.**

* For further discussions of the experiments and general suggestions regarding rations and formulas for feeding, see following article.

NITROGENOUS FEEDING STUFFS, AND FEEDING FORMULAS FOR DAIRY COWS.

BY W. O. ATWATER AND C. S. PHELPS.

NITROGEN AND THE FARMER—INVESTIGATIONS BY THE STORRS EXPERIMENT STATION.

One of the needs of farming in Connecticut, as in the older parts of the country generally, is more nitrogen. This nitrogen is wanted to make larger and better crops, better food for stock, and more and better food for man.

Plants get their nitrogen from the accumulated stores in the soil, from farm manures, from commercial fertilizers, and from the air. The amount available in most soils in the Eastern and Southern States is not enough for the largest and best yields of the majority of our common crops. The nitrogen of manures and fertilizers increases the yields of grasses, grains, potatoes, and root crops. Not only does the nitrogen increase the yield of these crops, but it also increases the proportion of nitrogen they contain in relation to the other substances. The value of the product is thus increased in a two-fold way. Grasses grown on well-manured soil yield more pounds per acre, and if the manure contains abundant nitrogen the crop will contain more nitrogen per pound. In the same way nitrogenous manures increase the yield of corn, oats, and wheat per acre and the crop is richer in nitrogen, pound for pound, than that grown with less nitrogen.

The value of nitrogen for increasing the growth of grasses, cereals, potatoes, and root crops, has long been known. Its effect in improving their quality has been brought out by later experiment, but is not so well or so generally understood.*

Nitrogenous fertilizers, however, do not increase in like degree the yields of the leguminous crops. Red clover, alsike, scarlet, and other clovers, cow peas, soy beans, ordinary

* The subject is being studied by the Storrs Station as may be seen in the articles on Field Experiments with Fertilizers in its Annual Reports for 1888–1896.

beans, peas, and other legumes do not respond so well as grasses and the common grains to nitrogenous fertilizers. They have the power of gathering the nitrogen from the air; that is, they can acquire this valuable ingredient for themselves if they have a sufficient amount of the other elements of plant food at the disposal of their roots in the soil.* They give good yields with mineral fertilizers, as phosphoric acid, potash salts, ashes, lime, plaster, and the like. The legumes contain large proportions of nitrogen. When fed to stock they supply the nitrogen which ordinary hay, straw, corn stalks and corn meal lack, and thus help to make well-balanced rations. They make manure rich in nitrogen. The stubble and roots left behind in the soil, like the stems, leaves, and seeds used for fodder, contain large amounts of nitrogen, and this becomes available for succeeding crops. And finally they seem to otherwise favor the accumulation of nitrogen in the soil. In all these ways they help the farmer to the nitrogen needed for manure, crops, and fodder.

The farmer can increase his nitrogen supply, then, by purchase, or by growing legumes. He can buy it in nitrate of soda, sulphate of ammonia, fish scrap, tankage, and other nitrogenous commercial fertilizers; or he can buy it in the concentrated nitrogenous foods like cotton seed meal, linseed meal, or wheat bran; or he can grow leguminous crops and get it from the air for nothing. In buying nitrogenous fertilizers he pays out his money and in return gets material to improve his fodder for his stock, and to make better manure on his farm to improve his crops. In growing legumes he pays out nothing for the nitrogen they gather from the air and at the same time he has the material to improve the fodder for his stock and the manure for his crops. The nitrogen in plant food and its relation to the growth and value of farm crops has been one of the principal subjects of investigation by the Storrs Station since it was first organized. The work has been done not only in the laboratory, but also in the field, and, with the rest, a large number of experiments have been made by farmers in different parts of the State who have coöperated with the Station by conducting tests on their own farms.

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* See Storrs Station Bulletin No. 5, Oct., 1889, and Annual Reports for 1889 and 1890, for accounts of experiments on this subject.

The growing animal needs nitrogen in the form of what the chemist calls protein, proteids, or albuminoids, to build up the body, to make blood and muscle, tendon and bone. The young calf and the lamb get the protein they need from the casein of milk. The growing lamb and steer, the ox and cow and horse and sheep get it from grasses, grains, and other feeding stuffs. Both the growing animal and the adult animal use protein to make up for the wear and tear of muscle, bone, and tendon; in other words, for the building and repair of the body.

The body also needs material for fuel to supply it with heat to keep it warm, and muscular strength for its work. Protein can be used for this purpose, but it is relatively too expensive. The principal fuel materials of food are the carbohydrates, like the starch of potato, wheat, and corn, and the similar compounds which occur in the grasses and other coarse fodders. The oils and the fatty substances, of which the grasses, grains, and roots contain very little, and cotton seed, linseed, and other oil meals contain much more, serve the same purpose as the carbohydrates in supplying the body with fuel. This especial subject is referred to more in detail beyond. It will suffice here that, considering the body as a machine, it is built up of protein, and the carbohydrates and fats are its fuel. The important fact for the Connecticut farmer to consider is that the feeding stuffs, as he ordinarily grows them, do not have enough protein. This is the real reason why he buys bran and oil meal and the like; and is one of the important reasons for his growing leguminous crops.

A great deal is said now-a-days about well-balanced rations for stock. This means rations with the right proportion of building material to fuel, of nitrogenous to carbonaceous nutrients, of protein on the one hand to fat and carbohydrates on the other.

We speak of "wide" and "narrow" rations. A wide ration is one with a large proportion of carbohydrates and fats to protein, and a narrow ration is one that has a relatively larger proportion of protein to carbohydrates and fats. A narrow ration has a relatively large amount of material to build up the machine and to keep it in repair, while a wide ration is one with a large amount of fuel.* One result of a large

* Report of Storrs Experiment Station for 1894, pp. 205-221.

amount of experimenting with animals by experiment stations and otherwise, in this country and in Europe, has been to give us tolerably clear ideas of the proportions of building material and fuel best adapted to the wants of farm animals of different kinds.

The principles thus brought out by scientific investigations have been constantly put to the test of practical experiment on many farms and in many stables. Here, as in the field experiments, the results have been most encouraging. This union of science and practice, this development of theory by the investigator and testing by the feeder and the dairyman, has thrown a great deal of light upon things which, a few years ago, were doubtful or unknown. The Storrs Station has shared in this movement. It has made chemical investigations in the laboratory and feeding experiments with cows and sheep in the field and stable. It has joined forces with intelligent and progressive farmers and dairymen in different parts of the State, and a considerable number of actual tests have thus been made.

The digestion experiments of this as of other experiment stations are made by taking animals of different kinds, giving them certain amounts of different food materials and noting the results. The food materials are weighed and chemically analyzed, and the same is done with the products given off from the body of the animal. A comparison of the weight and composition of the food and of the solid excrement, which latter contains the undigested residue of the food, shows how much of the food and of each of its ingredients is actually digested and used by the animal. Such digestion experiments show the proportion of protein, fats, and carbohydrates actually digested in green fodder, hay, grain, and the like. The Station has made a large number of analyses of the commercial feeding stuffs and has tested the digestibility of some of them by digestion experiments with sheep. The information thus obtained, added to that from other sources, is gradually showing us the chemical composition and nutritive value of our more common feeding stuffs.

The Station has also made a considerable number of experiments with milch cows, feeding them different materials and noting the amount and quality of the milk produced.* In

* Reports of Storrs Experiment Station, 1893–1897.

these experiments the value of the nitrogenous feeding stuffs, including the leguminous crops, such as clover, cow peas, soy beans, and their use for soiling and green fodder, have received particular attention.* The amount of work the Station has been able to do in this direction is very small indeed compared with that which has already been done and is accumulating in this country and in Europe. But by following up the investigations elsewhere and using these results in its own work the Station has obtained a large amount of information while it has added a little to the common fund.

In the coöperative experiments with farmers and dairymen an officer of the Station has spent a number of days at each place. A certain number of cows were selected from a herd and used for the tests. With the aid of the owner the feeding stuffs were weighed as they were fed out to the cows and samples were sent to the Station for analysis. The milk of each cow was weighed and the proportion of fat determined by the Babcock test. In this way experiments were carried out with a considerable number of cows in each herd. The tests showed what the farmers were actually feeding their cows and how much and how good milk each cow was giving. In a number of cases the Station suggested ways in which the feeding might be improved, the change consisting generally in the use of more of the nitrogenous feeding stuffs and in replacing the finer grade of hay by cheaper fodders. Tests were made in many cases after the change of fodder and in nearly every instance the change proved decidedly profitable. The work has been going on during the past four years and is being continued. The results obtained up to the present time have been set forth in previous Reports and in the preceding article of the present Report of the Station.

CLASSES OF NITROGENOUS FEEDING STUFFS.

Our common nitrogenous feeding stuffs may be divided into four groups: (1) The by-products left after the extraction of oil or starch from certain seeds such as cotton seed, linseed, and gluten meals; (2) By-products from the manufacture of flour, as wheat bran; (3) The seeds of the legumes, as peas; (4) The green and dry leguminous fodders, as clover.

* Report of Storrs Experiment Station for 1892 and Bulletin No. 9.

THE BY-PRODUCTS FROM OIL SEEDS.

Cotton seed Meal.—This is a by-product from the manufacture of cotton seed oil. It has come into quite extensive use in New England as a feeding stuff and as a fertilizer within the past fifteen years. Its value as food depends mainly on the flesh-forming material or protein it contains. It is also rich in fat, but is lacking in carbohydrates (starch, sugar, etc.), and in fibrous material to give bulk. It cannot be fed to the best advantage unless it is mixed with some of the coarser fodders rich in carbohydrates. The value of cotton seed meal for the production of beef, milk, and butter is well established. It is one of the cheapest of the nitrogenous feeding stuffs, and is especially valuable for balancing rations deficient in protein. It seems best to feed it mixed with other and lighter feeds like wheat bran and corn meal. Used in moderate quantities it has been found to increase the milk flow, to harden the butter, and to favor a more thorough creaming of milk by the gravity process. If fed in large amounts it may unfavorably affect the quality of the butter, especially the flavor, and endanger the health of the animal. The quantity that can be safely fed to a cow depends much upon the animal, and the amount of milk she is producing. Cows giving a large flow of milk have been fed as much as four or five pounds daily, without apparent injury. According to our experience two or three pounds per day is as much as can usually be fed with advantage to cows of 800 to 1000 pounds live weight. When fed in much larger quantities than this, garget frequently develops. The use of cotton seed meal in feeding pigs, sheep, and horses has not given as good results, and in a number of instances has caused serious injury. In several experiments in pig-feeding its use has been followed by the death of most of the animals in the course of from four to six months.

Cotton seed meal varies much in composition. The protein may range from 23 to 50 per cent., and the fat from 8 to 18 per cent. The bright yellow meals, which are comparatively free from the ground hulls, are considered the best.

Old Process Linseed Meal.—The oldest method of extracting oil from the flax seed was by pressure, and the feed formerly common in the trade was known as "oil cake," because this by-product was sold in large cakes just as it came from the oil

presses. In the earlier processes of manufacture in the United States these cakes were nine or ten inches thick, and contained from ten to fifteen per cent. of oil. In the later processes of manufacture the seed is subjected to a much higher pressure, and the "cake" comes from the presses in layers about one inch in thickness. This is commonly ground and sold as "old process linseed meal," and rarely contains over six to eight per cent. of oil. The nitrogenous matter, or protein, of all linseed meals is quite variable in amount owing to differences in soil and seasons, and in the degree of maturity of the flax seed. The old process "cake" or meal has been highly prized by practical feeders in England for fattening cattle for market, and especially for the show ring. It gives the animal a thrifty appearance, and produces the soft, shining coat, and the "mellow" skin, so important for exhibition purposes. It is also considerably used in that country for feeding horses. In this country it has been used to a limited extent in fattening cattle and in feeding for milk. About two pounds per day for animals of 800 to 1000 pounds live weight will, according to our experience, generally give good results. Where high-grade butter is the object sought not over two pounds per day should be fed. If more is used the flavor of the butter may be affected. Where succulent foods, such as silage or roots, are not available this meal may serve as a substitute by acting as a laxative. Its chief value is for the protein and oil it contains, and for these materials mainly it should be fed. The old process meal varies from 27 to 38 per cent. in protein and 5 to 12 per cent. in fat.

New Process Linseed Meal.—Another process of extracting the oil from the flax seed is by soaking it in large vats of naphtha. After soaking for a time the solution of oil and naphtha is drawn off and a new lot of naphtha is added. The process is thus repeated about a dozen times until the quantity of oil remaining in the seed is reduced to about 3 per cent., after which the naphtha is evaporated and the meal dried. The new process meal will vary from 27 to 40 per cent. in protein and from 1 to 4 per cent. in fat. In some of the more recent methods of extracting the oil the new process by-product is found to average 35 to 40 per cent. of protein and not over 3 per cent. of fat.

The chief differences in composition of old and new process meals are the smaller percentage of oil and the slightly larger percentage of protein found in the new process. Other things being equal, it would be expected that the new process meal, owing to its larger content of protein, would have a higher feeding value. Digestion experiments thus far made, however, imply that the protein of the old process is somewhat more digestible, so that the composition of the two meals on the basis of digestible nutrients is very similar. The relative advantages of the old and new process meals must depend mainly upon their costs, upon the purpose for which the feeding is done, and upon the other feeds used in making up the ration.

BY-PRODUCTS FROM THE MANUFACTURE OF GLUCOSE AND STARCH FROM CORN.

Gluten Meals and Gluten Feeds.—Much confusion exists as to the meaning of the different terms applied to these by-products from the manufacture of glucose. They all come primarily from corn. The dry (water-free) matter of the corn kernel contains not far from 75 per cent. of starch and 12 per cent. of nitrogenous matter or protein. The starch is largely extracted from the corn for use in the manufacture of glucose, leaving a by-product rich in gluten (protein). The different products found in the markets, sold under the name of gluten, are the by-products obtained in the process of separating the starch from the grain. The corn is first soaked in water for some hours, then coarsely ground and rubbed between "loosely set" mill stones, which removes the hulls and sets free the starch cells. The material is then put on sieves of fine bolting cloth, and the starch and gluten pass through while the germs and hulls remain on the sieves. The starch and gluten which go through the sieves are then forced through troughs or tanks of water and separated.

The husks and germs of the corn remaining on the sieves are dried and placed on the market directly, or else treated with naphtha to remove most of the oil of the germs and are sold as *gluten feed*. The final residue obtained from the settling tanks, which is largely the gluten and oil of the corn, is dried and sold as *cream gluten*, or else the oil is extracted from it and the residue united with the germs and sold as gluten meal. Sometimes the corn hulls and germs are sold separately under the trade terms *corn bran* and *germ meal*.

Some prejudice exists against the use of gluten feeding stuffs, because of the belief that the sulphuric acid used in the manufacture of glucose affects the gluten feeds. This prejudice is entirely unwarranted, as all of these by-products come directly from the corn by mechanical means of separation before the manufacture of the glucose is begun.

The various gluten feeds have, in recent years, come into use very largely for feeding milch cows. They have been used with good results for increasing the quantity of milk, and the only objectionable effect noticed on butter has been a slightly softer texture. This may be overcome by using the glutens in connection with cotton seed meal. The chief difference in the composition of the glutens is in the amount of protein, and their relative values can be estimated very closely by the percentages of this constituent contained in them. The gluten feeds, owing to the presence of the corn hulls, contain considerably more fibre and starchy materials and less of the protein than do the gluten meals. The gluten feeds will vary from 12 to 24 per cent. in protein and from 9 to 14 per cent. in fat, while the gluten meals contain from 25 to 38 per cent. of protein and 4 to 12 per cent. of fat.

BY-PRODUCTS FROM THE MANUFACTURE OF FLOUR.

The principal by-products from the manufacture of flour are wheat bran and wheat middlings. Other cereals, such as rye and buckwheat, afford by-products of considerable value, but these are found in the trade to only a limited extent. There are other trade terms in use to designate certain by-products of wheat, such as wheat feed, ship stuff, shorts, flour feed, etc. Many of these vary greatly in composition, and are often composed in part of corn, oats, or other mill products. The terms are so misleading and the composition so variable that it is usually wise to avoid buying these products except on guaranteed analysis. Wheat bran and wheat middlings generally mean definite products, and while they vary somewhat in composition this is due mainly to variations in the original grain from which they are made.

Wheat Bran.—This by-product consists of the outer covering of the wheat kernel with but very little of the flour. When not ground it is a bulky feed of great value for mixing with

the heavier grain feeds. The proportion of the various nutrients is so well balanced that it is one of our safest feeds. It constitutes a portion of nearly every grain ration used by dairymen. The outer coverings of the wheat seed contain more nitrogen and less starch than the inner parts from which the flour is made. Wheat bran varies in protein from 12 to 19 per cent., averaging about 15.4 per cent. It is quite well digested by the ruminants, although samples tested by this Station were not as highly digestible as wheat middlings.

Wheat Middlings.—This feed is supposed to consist of those coverings of the wheat seeds just beneath the hulls, including a small part of the darker colored flour, but the "fine" middlings often include a considerable part of the flour.

When but little flour is present the middlings contain more protein than does wheat bran. The better grades are also more digestible. The presence of the flour does not add materially to its value, as it favors the fattening of the animal. Owing to its fineness middlings can be fed to better advantage mixed with wheat bran to add bulk. Wheat middlings contain from 10 to 20 per cent. of protein, averaging 15.6 per cent.

SEEDS OF LEGUMES.

The only seeds of legumes that have been used to any considerable extent in feeding in this region are the Canada pea, the soy bean, and the cow pea.

Canada pea meal is found in our feed markets only to a limited extent. It contains about 20 per cent. of protein and 1 to 2 per cent. of fat. The peas are, however, quite extensively grown with oats for home use. The two crops can be grown, harvested, and fed together, and the mixed seeds make a much better feed than oats alone.

"*Split Pea refuse*" *and* "*Culled Peas.*"—The former of these is a by-product from the split pea factories, and is made from the hulls, broken peas, and other refuse that is rejected from the peas used as food for man. The meal made from this refuse has about 5 per cent. less protein than the regular pea meal. The smaller and more immature peas are also rejected by some manufacturers of split peas, and are sold to feeders as "culled peas." Specimens of these immature peas which we have examined contain relatively more protein than

the ordinary pea meal or the "split pea refuse." All of the pea meal products have proven particularly valuable for fattening lambs, being used with greater safety than most other nitrogenous feeds for this class of stock. They have also been fed to some extent in milk production.

Soy beans are being introduced into this country for use as a grain feed, and as a home-grown source of protein are worthy of the thoughtful consideration of farmers. The meal of soy beans is nearly equal to cotton seed meal in the quantity of protein it contains. The soy bean meal has been experimented with only to a limited extent in feeding milch cows, but as far as it has been fed it is found to compare closely in feeding value with cotton seed meal. The medium early white variety is the one most grown for seed, and the meal of this contains from 31 to 37 per cent. of protein. Farmers would do well to experiment with the soy bean and ascertain its value as a farm crop for use in feeding dairy stock.

The *Cow pea* will not mature seed in Connecticut, and the meal has not been found in our markets. In the South it has been largely grown, both for its seed and as a forage crop, and farmers there are using the cow pea meal in feeding nearly all kinds of farm stock.

GREEN AND DRY FODDERS OF THE LEGUMES.

The principal leguminous fodders of value for feeding green, or for drying as hay, are the clovers, Canada peas, soy beans, and cow peas. Details with regard to growing these crops have been given in Bulletin 17 of the Station. Their advantage over the hays of grasses, corn fodder, and stover for feeding is due mainly to the larger quantities of protein they contain. When plenty of clover is available for feeding dairy stock less of such feeds as cotton seed, linseed, and gluten meals need be purchased. Some of the coarse growing legumes like the cow pea and soy bean, which cannot be readily cured and preserved dry, may be made into silage. By mixing them with corn fodder in filling the silo a mixed silage of greater value than that made from corn alone may be obtained.

Clovers.—All of the clovers are far more valuable to feed than the ordinary hay of grasses. Thirty-six analyses of common red clover hay, compiled by Jenkins and Winton,* show a

* U. S. Dept. Agr., Office of Experiment Stations, Bulletin No. 11. A Compilation of Analyses of American Feeding Stuffs.

range of from 10 to 20 per cent. in protein, while 67 analyses of timothy show a range of 4 to 10 per cent. in protein. Otherwise the composition of the two crops does not differ materially. Judged on the basis of protein alone, the clover hay would be twice as valuable to feed as timothy hay. The clovers, when cut in the earlier stages of development, are also more highly digestible than the timothy. Our common clovers are pretty certain to produce two crops a year, while timothy often produces but one. The alsike clover is fully as nutritious as the common red, and is more valuable for growing upon heavy, clayey soils. The white clover is more nutritious than most of the other varieties, but the yields are rather light. Its chief value on the farm is to grow in pasture mixtures. It will withstand close cropping and constant tramping, and retain a firm turf.

Oat and Pea Hay.—Oats have long been used and highly prized as a hay crop, but it is only within a few years that our farmers, generally, have appreciated the great value of Canada peas for growing with the oats. The amount and proportion of seed of each to be used should vary according to the soil. On very rich soil 1 bushel of peas to 2 bushels of oats will give good results. On most soils 1½ or 2 bushels of peas and 2 bushels of oats per acre have been found a good rate of seeding. The larger the proportion of peas the richer in protein will be the fodder, but there is danger of the crop lodging badly if the proportion of peas used exceeds one-half. Oat hay usually contains from 6 to 10 per cent. of protein, while the oat and pea hay contains from 10 to 18 per cent., depending on the proportion of peas in the mixture. The composition of the oat hay is much like that of timothy, while the oat and pea hay compares favorably with clover hay. The oat and pea hay, the composition of which is given in table 12, contained a smaller percentage of protein than that indicated above. This is probably due to the fact that its proportion of peas was small.

Soy Bean and Cow Pea Fodders.—These two crops are coming into favor for green feeding and for silage. The composition and the yields per acre of the two crops are much alike. The soy bean will withstand cool weather better, although both are injured by frost. The soy bean also stands up better

and can be mowed by hand or machine easily, while the cow pea branches close to the ground and is harvested with difficulty. They can best be used as silage crops, and may be mixed with corn silage as the silo is being filled. According to our experience the medium green soy bean gives the largest yields of that fodder, while the Clay is one of the best varieties of the cow pea. Compared with corn fodder the yields of either the cow pea or soy bean are one-third to one-half less, while the percentage of protein is fully twice as much as in the corn. A silage of soy beans and corn gives a better balanced ration than corn alone, and seems to be well eaten by cows.

COMPOSITION AND DIGESTIBILITY OF FEEDING STUFFS.

Table 11, which follows, shows the average composition of a number of kinds of nitrogenous feeding stuffs as commonly grown and sold in this region. They may be divided into (1) coarse fodders, as clover hay, rowen hay, and oat and pea hay; and (2) concentrated feeding stuffs, as wheat bran, cotton seed meal, and other milling and by-products of the grains and seeds. For comparison are given the averages of analyses of several kinds of feeding stuffs low in nitrogenous matter (protein) such as corn silage, the hay of grasses, corn meal, etc.

At the left of table 11 is given the average composition of our more common nitrogenous (protein) feeding stuffs. The figures are based in nearly all cases on the actual water content of these materials as used for feeding or found for sale in the market.

At the right are given the percentages of protein, fat, and carbohydrates which are actually digested by the animals, as calculated by the use of the digestion factors given in the table of digestibility. These results are obtained by multiplying the percentage of nutrients as given on the left of table 11 by the coefficients of digestibility given in table 12. It will be noticed that the term carbohydrates is used in the right-hand columns under digestible nutrients, but does not appear in the left-hand side of the table. The carbohydrates include the digestible nitrogen-free extract and the digestible fiber. The digestible portions of these two materials have been found to be quite similar in feeding value, and hence they are included under one term (carbohydrates) in stating the digestible composition of a fodder.

TABLE II.

Composition of nitrogenous feeding stuffs, including both total nutrients and digestible nutrients.

Classes and Kinds of Feeding Stuffs.	Number of Analyses.	Percentage Composition and Total Nutrients. Water.	Protein.	Fat.	Nit.-free Extract.	Fiber.	Ash.	Fuel Value.†	Digestible Nutrients. Protein.	Fat.	Carbo-hydrates.	Fuel Value.†
Green Fodders and Silage.		%	%	%	%	%	%	Cal.	%	%	%	Cal.
Barley and pea fodder,	4	80.5	3.9	.8	8.2	5.0	1.6	350	3.0	.5	7.2	210
Scarlet clover fodder, -	3	85.2	2.7	.7	6.1	3.9	1.4	260	2.1	.4	6.7	180
Canada pea fodder, -	2	86.5	3.7	.7	4.7	2.9	1.5	240	3.0	.4	5.2	170
Flat pea fodder, - -	1	84.1	4.8	.9	4.6	4.3	1.3	295	3.2	.6	5.9	195
Timothy rowen, - -	2	67.2	5.2	1.9	14.9	8.1	2.7	610	3.8	1.0	15.3	395
Clover rowen, - -	2	74.4	4.3	1.3	11.1	6.7	2.2	465	2.7	.8	10.7	285
Cow pea fodder, - -	40	82.6	3.0	.6	8.1	3.8	1.9	305	2.2	.4	8.9	225
Oat and pea fodder, -	7	81.3	3.4	.8	7.7	5.0	1.8	335	2.7	.6	8.0	225
Soy bean fodder, -	11	75.4	3.6	1.0	11.1	6.5	2.4	440	2.7	.5	11.1	280
Clover, red, - - -	10	78.6	3.9	.8	9.0	5.7	2.0	380	2.6	.5	10.1	255
Vetch fodder, - -	3	81.0	3.9	.4	6.3	5.7	2.7	305	3.0	.2	7.2	200
Vetch and oat fodder,	7	76.2	2.6	.7	10.8	7.6	2.1	400	1.6	.1	10.9	235
Corn and soy bean silage,	4	76.0	2.5	.8	11.1	7.2	2.4	420	1.6	.7	13.0	300
Cured Fodders.												
Alfalfa, - - -	8	10.3	13.3	1.9	39.6	27.5	7.4	1575	9.7	1.0	39.6	960
Clover, alsike, - -	6	10.3	13.4	3.0	39.6	24.6	9.1	1570	8.8	1.5	41.2	995
Clover, red, - - -	10	8.3	13.3	2.2	41.9	26.5	7.8	1610	6.9	1.0	38.0	877
Scarlet clover hay, -	2	16.8	14.8	1.9	30.9	28.3	7.3	1455	10.2	.8	31.6	815
Oat and pea hay, -	2	16.8	9.7	3.4	37.9	25.8	6.4	1510	5.8	.6	37.5	830
Rowen, mixed grasses,	8	15.3	13.6	3.3	38.1	23.7	6.0	1540	9.4	1.6	40.0	985
Clover rowen (early cut),	6	11.2	15.5	3.5	39.1	23.9	6.8	1610	10.1	2.1	35.9	945
Serradella hay, - -	3	9.2	15.2	2.6	44.2	21.6	7.2	1615	11.4	1.7	38.6	1000
Vetch hay, - - -	5	11.3	17.0	2.3	36.1	25.4	7.9	1557	12.9	1.4	37.5	995
Vetch and oat hay, -	2	14.1	10.5	2.4	36.6	29.6	6.8	1528	6.3	.5	39.3	870
Milling and By-Products.												
Oat feed, - - -	20	7.5	11.1	4.0	57.3	15.1	5.0	1720	8.7	3.4	48.0	1200
Oats and peas, - -	2	11.5	23.1	2.5	52.5	7.1	3.3	1640	18.7	1.6	48.1	1310
Soy bean meal, - -	16	10.7	34.6	18.5	26.7	3.3	6.2	1980	29.8	15.7	21.9	1625
Pea meal, - - -	2	10.5	20.2	1.2	51.1	14.4	2.6	1645	16.8	.6	51.8	1300
Buffalo gluten feed, -	*	10.5	26.2	3.8	53.0	5.2	1.3	1730	22.5	3.3	49.0	1470
Chicago gluten meal, -	16	9.0	35.4	6.2	46.1	2.3	1.0	1820	31.5	5.7	43.6	1638
Cream gluten meal, -	5	8.0	36.1	13.0	40.7	1.5	.7	2005	30.3	12.7	36.3	1775
Malt sprouts, - -	4	10.2	23.2	1.7	48.5	10.7	5.7	1605	18.6	1.7	37.1	1108
Wheat bran, - -	88	11.9	15.4	4.0	53.9	9.0	5.8	1625	11.9	2.8	38.5	1055
Wheat middlings, -	32	12.1	15.6	4.0	60.4	4.6	3.3	1675	12.1	3.5	50.4	1310
Cotton seed meal, -	35	8.2	42.3	13.1	23.6	5.6	7.2	1880	37.2	12.2	16.9	1520
O. P. linseed meal, -	21	9.2	32.9	7.9	35.4	8.9	5.7	1770	29.3	7.0	32.7	1450
N. P. linseed meal, -	14	10.1	33.2	3.0	38.4	9.5	5.8	1635	28.6	2.7	35.4	1305
Cleveland flax meal, -	1	9.9	40.2	2.5	34.5	7.6	5.3	1635	34.2	2.3	34.6	1377

* Recent analyses show that the manufacturers of Buffalo gluten feed are removing a large part of the oil that was formerly left in the feed. For this reason the percentage composition of Buffalo gluten feed as given in the table is an average of a few recent analyses made at this Station and at the Massachusetts Experiment Station and not an average of all analyses available.

† Per pound.

TABLE 11.—(*Continued.*)

Classes and Kinds of Feeding Stuffs.	Number of Analyses.	Percentage Composition and Total Nutrients. Water.	Protein.	Fat.	Nit.-free Extract.	Fiber.	Ash.	Fuel Value.*	Digestible Nutrients. Protein.	Fat.	Carbo-hydrates.	Fuel Value.*
Feeding Stuffs low in Nitrogen, for Comparison.		%	%	%	%	%	%	Cal.	%	%	%	Cal.
Corn silage, - -	14	75.4	1.9	.9	14.0	6.4	1.4	455	1.0	.7	14.1	310
Cured Fodders.												
Timothy, - - -	67	13.2	5.9	2.5	45.0	29.0	4.4	1590	2.8	1.5	43.5	925
Red-top, - - -	7	8.9	7.9	1.9	47.5	28.6	5.2	1645	4.8	1.0	46.9	1005
Orchard grass, - -	11	9.9	8.1	2.6	41.0	32.4	6.0	1625	4.9	1.4	42.4	940
Kentucky blue grass, -	8	11.1	7.3	4.1	40.5	29.0	8.0	1600	4.5	2.1	42.9	970
Hay, mixed, - -	66	14.0	8.1	2.4	43.3	26.9	5.3	1560	4.8	1.2	41.6	915
Oat hay, - - -	12	11.6	8.4	3.3	43.4	27.9	5.4	1620	4.5	2.0	34.8	815
Hungarian, - - -	13	7.7	7.5	2.1	49.0	27.7	6.0	1655	4.5	1.3	51.7	1090
Corn stover, - -	174	14.3	5.5	1.7	43.8	29.3	5.4	1535	2.5	1.1	46.2	950
Milling and By-Products.												
Corn meal, - - -	23	12.9	9.6	4.5	69.9	1.6	1.5	1700	5.8	4.1	65.9	1505
Hominy chop, - -	1	9.6	10.8	8.2	64.3	4.5	2.6	1825	6.5	7.5	62.4	1600

Composition.—The most important difference in the coarse fodders is in the proportion of protein. The nitrogenous green fodders, and the hay of legumes, contain from one and one-half to two times as much protein as the grasses and corn fodders, stover, and the like.

There are numerous conditions which tend to modify the composition of coarse fodders, especially of grasses and grains. The manure or fertilizers used in growing the crop affects the composition to a marked degree. This is especially true of the nitrogenous fertilizers, the free use of which tends to increase the proportion of nitrogen and protein in the grasses and grains, while the legumes appear to be much less affected by them. The composition also varies more or less with soil and the season, while the method of curing and handling the crop may modify the composition quite largely. Excessive drying will cause the leaves and finer parts to fall off and become lost, while washing by rains will extract a considerable part of the more valuable nutrients, thus relatively increasing the percentage of woody fiber and lessening the starch and protein.

The stage of maturity in which the crop is harvested has a very marked influence upon the composition. If allowed to

* Per pound.

remain uncut until after the blossoming stage, the plant will increase rapidly in woody fiber, and decrease relatively in the amount of digestible protein.

Digestibility.—The composition of a fodder is not the full measure of its value. A part only of each of the nutrients, protein, fat, etc., becomes available to the animal, hence the amount of food materials actually digested or extracted from the food eaten becomes an important factor in estimating its value. The composition of the fodder, the degree of maturity at which it is harvested, and the kind of animal are the principal factors modifying the digestibility of feeding stuffs.

The leguminous fodders as a class (with the possible exception of red clover) are more digestible than the grasses, as shown by a large number of digestion experiments made both in this country and in Europe. It is a common fact, if not a general rule, that the larger the proportion of protein and the smaller the proportion of starchy materials, and especially of woody fiber contained in any feeding stuff, the larger will be the proportion of the principal nutrients digested by the animal. Hays, straws, cornstalks, and the like contain considerable amounts of material known as "woody fiber" or lignin, which is not easily ground up in chewing and resists the action of the digestive fluids. These substances encase more or less of the valuable nutrients—the protein, fat, starch, etc.—and hinder the action of the digestive fluids upon them. Hence, such coarse fodders are much less digestible than those which have less woody fiber.

The degree of maturity of the crop has a marked effect upon its digestibility. Soon after the blossoming stage the proportion of woody fiber, including the lignin, increases rapidly. This tends to encase the more digestible portions and to prevent their being acted upon freely by the digestive fluids or by the mechanical processes of digestion.

Different classes of animals digest food materials somewhat differently. The horse, for example, does not digest coarse fodders as completely as do the ruminants. It has been found by numerous experiments that the ruminants or cud-chewing animals, such as the cow and the sheep, digest their food essentially alike, so that the results of digestion experiments with sheep are fairly applicable to all cattle.

TABLE 12.

Coefficients of digestibility of nitrogenous feeding stuffs.

KIND OF FEEDING STUFFS.	No. of Trials.	Protein.	Fat.	Nitrogen-free Extract.	Fiber.
Green Fodders and Silage,		Per Cent.	Per Cent.	Per Cent.	Per Ct.
* Barley and pea fodder, -	2	77	60	61	44
* Scarlet clover fodder, - -	3	77	66	74	56
* Canada pea fodder, - -	2	82	52	71	62
* Flat pea fodder, - - -		Assumed	as red	clover.	
* Timothy rowen, - - -	4	72	52	68	64
* Clover rowen, - - -	2	62	61	65	52
† Cow pea fodder, - - -	2	74	59	84	57
† Oat and pea fodder, - -	2	81	74	66	58
† Soy bean fodder, - - -	4	74	54	73	45
† Red clover, - - - -	2	67	65	78	53
‡ Vetch fodder, - - -	—	76	60	66	54
† Vetch and oat fodder, - -	2	60	19	54	66
† Corn and soy bean silage, -	3	65	82	75	65
Cured Fodders.					
‡ Alfalfa, - - - - -	—	73	51	68	46
† Alsike clover, - - -	3	66	50	71	53
† Red clover, - - - -	4	52	48	61	47
* Scarlet clover hay, - -	7	69	43	61	45
Oat and pea hay, - -		Assumed	as oats	and vetch.	
* Rowen, mixed grasses, -	12	69	48	64	66
* Clover rowen (early cut), -	4	65	60	63	47
‡ Serradella hay, - - -	—	75	65	63	50
‡ Vetch hay, - - - -	—	76	60	66	54
† Vetch and oat hay, - -	2	60	19	54	66
Milling and By-Products.					
‡ Oat feed (assumed as oats), -	11	78	84	77	26
‡ Oats and peas (two-thirds peas),	—	81	64	88	26
* Soy bean meal, - - -	8	86	85	73	73
† Pea meal, - - - -	2	83	54	94	26
† Buffalo gluten feed, - -	4	86	87	84	66
† Chicago gluten meal, - -	2	89	93	93	33
† Cream gluten meal, - -	2	84	98	88	33
† Malt sprouts, - - -	1	80	100	69	34
†*Wheat bran, - - -	15	77	69	68	20
†*Wheat middlings, - -	8	79	87	81	33
† Cotton seed meal, - -	6	88	93	64	32
*† O. P. linseed meal, - -	3	89	89	78	57
‡ N. P. linseed meal, - -	—	86	90	80	50
† Cleveland flax meal, - -	3	85	93	84	74
Feeding Stuffs low in Nitrogen, for Comparison.					
† Corn silage (with ears), -	51	52	79	70	67
Cured Fodders.					
† Timothy, - - - - -	26	48	60	63	52
† Red top, - - - - -	3	61	51	62	61

*Storrs Station. †Hatch (Mass.) Experiment Station. ‡German.

TABLE 12.—*(Continued.)*

KIND OF FEEDING STUFFS.	No. of Trials.	Protein.	Fat.	Nitrogen-free Extract.	Fiber.
Cured Fodders. (Continued.)		Per Cent.	Per Cent.	Per Cent.	Per Ct.
† Orchard grass, - - -	3	60	55	55	61
* Kentucky blue grass, - -		Assumed	as red-	top.	
† Hay (mixed grasses), - -	20	58	48	59	60
* Oat hay, - - - - -	4	53	61	52	44
† Hungarian, - - - -	2	60	64	67	68
† Corn stover, - - -	8	45	62	61	67
Milling and By-Products.					
† Corn meal, - - - -	5	60	92	93	58
Hominy chop, - - -		Assumed	as corn	meal.	

* Storrs Station. † Hatch (Mass.) Experiment Station. ‡ German.

In the preceding table are given average digestion factors obtained mainly from American digestion experiments. The figures indicate the percentages of the various nutrients, protein, fat, etc., which are actually digested by the animals. Many of these are the results of our own digestion experiments with sheep, which will be found summarized in the Report of this Station for 1896, others are from a compilation of American digestion experiments by Dr. J. B. Lindsey,§ while a few are from German experiments.||

IS THE QUANTITY OF DIGESTIBLE NUTRIENTS A TRUE MEASURE OF FEEDING VALUE?

It has been very frequently assumed that the same kinds and amounts of digestible nutrients have the same value whatever their source. This would mean, for instance, that a pound of digestible protein or carbohydrates from oat straw or corn stover would have the same nutritive value as a pound of digestible protein from corn meal or gluten meal. Practical feeders, on the other hand, have always questioned this theory. Late research is helping to clear up the matter by showing that a considerable amount of the nutriment in food is used by the body in the labor of digestion, and that the quantity of material needed to prepare the coarse fodders for use in the body is much larger than with the concentrated fodders. The larger the amount of

§ Hatch (Mass.) Experiment Station, Report 1896.

|| See Report of this Sation, 1893, pp. 156–167, and compilation by Prof. W. H. Jordan, U. S. Dept. Agr., Experiment Station Record, Vol. VI. (1894, 1895), pp. 5-8.

woody fiber and other "ballast," the more muscular work is required for chewing the food and for moving it through the alimentary canal. At the same time much more energy is required to supply the digestive juices for handling this material. In other words, the unequal "ease of digestion" brings it about that the actual nutritive values of the food materials are quite different from those calculated simply from their composition. It has been estimated that the nutrients which are assimilated from coarse fodders may yield the organism one-fifth less energy for its ordinary work than the same amount assimilated from grain, since the coarse fodder requires so much more energy for its digestion. This means that a given number of pounds of actually digestible protein, fat, and carbohydrates in coarse fodder are really worth considerably less for feeding than the same amount in a more digestible concentrated fodder.

The following statements by Prof. Zuntz of the Royal Agricultural High School, Berlin, Germany, who has devoted much experimental inquiry to these subjects, are of especial interest:*

"It must be said that even when an animal performs no external muscular labor, nutrients must still be metabolized for the production of energy. This energy is required for the beating of the heart, the muscular movements of respiration, and in much greater degree for the processes of digestion. Accurate measurements have been made of the energy expended in digesting food. The increase in the consumption of oxygen when food is chewed has also been determined and found to be equal to 51 to 59 per cent. of the amount consumed when no work is done.

"It is well known that it takes a horse much longer to chew 1 kilogram of coarse fodder than the same amount of grain. It has been found that the oxygen consumption increases 11.4 liters† for the labor of chewing 1 kilogram‡ of oats, 7.7 liters for 1 kilogram of corn, and 33.7 liters for 1 kilogram of hay. From these figures the quantity of nutrients which must be metabolized to carry on the work of chewing can be calculated. For oats it is found to be 2.8 per cent. of the total quantity assimilated, for corn 1.4 per cent., and for hay 11.2 per cent. Closely connected with the labor of chewing and swallowing is that expended in the muscular movements of the stomach and intestines and in the secretion of digestive juices by the various glands. The amount of this work, as well as the material necessary to maintain it, may in a way be estimated by comparing the increased consumption of oxygen during the few hours immediately following the consumption of food with that observed during hunger. It might be thought that this increase was due to the presence of the nutrients taken into the circulation; that is, that the nutritive materials used were increased

* Experiment Station Record, Vol. VII., pp. 547, 548.

† One liter is 1.06 quart, liquid measure. ‡ One kilogram is very nearly 2.2 pounds.

with the amount supplied, as in the case of the fuel placed in the stove; but this comparison is not apt. The amount of oxidation in the organism is influenced solely by the amount required for performing labor or producing heat, and not at all by the amount of nutrients which may be present. This has been shown by von Mering and Zuntz.* They introduced solutions of nutrients in considerable quantity directly into the blood of animals and found that the consumption of oxygen was not at all increased. The extra nutrients were stored up by the animal as reserve material. Therefore the increased oxygen consumption immediately after eating can only be produced by the labor of digestion.

"In feeding with a normal mixture of oats and hay the increased oxygen consumption is 10.7 per cent., and when hay only is fed, the amount being just sufficient to maintain the animal and permit a very little work to be done, it is 19.8 per cent. in excess of the amount of oxygen consumed when fasting. In this case also it may be seen that the bulky hay requires more energy for its digestion than the more concentrated food."

"It is evident that the unequal 'ease of digestion' materially changes the nutritive value of feeding stuffs from the values which are derived simply from their chemical composition. The nutrients which are assimilated from coarse fodder yield the organism about 20 per cent. less available energy than the same amount assimilated from grain, since the coarse fodder requires so much more energy for its digestion.

"Respiration experiments furnish accurate information concerning the quantity of nutrients which is required for the performance of various kinds of work. They show more clearly than any previous method how much of the energy of the assimilated nutrients is available for the organism after the labor of digestion is accomplished. They give no information, however, as to what combination of nutrients is best suited for the production of the greatest possible amount of muscular energy.

"The general practice of feeding work animals a ration rich in protein is in harmony with Pflüger's observations. The dog which he fed for months on meat only was able to perform severe muscular labor. Often, however, even dogs could not digest a sufficient amount of protein. On a diet of protein the digestive juices which are adapted for the assimilation of fat and carbohydrates are not utilized. When it is desired to feed an animal a ration which will give the maximum amount of work, a combination of nutrients must be selected which will utilize all the energy available for digestion. Care must be taken also not to feed too much coarse fodder, since it has been seen that such food materially increases the labor of digestion. On the other hand, coarse fodder must not be omitted altogether. Grandeau and Leclerc† have shown that disturbances of the digestive organs are produced when horses are fed entirely on grain. At all events, grain should form the greater part of the ration of horses which perform severe work."

FOOD REQUIREMENTS OF THE ANIMAL ORGANISM.

The animal uses its food for various purposes, the chief of which are: (1) To build up the tissues and fluids of the body, which may be regarded as a machine, and to keep it in

* Pflüger's Arch. Physiol., 32, p. 173.

† Études expérimentales sur l'alimentation du cheval de trait, 1883, 1887, and 1889.

repair as it is being constantly worn out; and (2) to yield energy in the form of heat to keep the body warm, and in the form of power for the work it has to perform. The chief building materials of the food are the protein or nitrogenous compounds. These build up and repair the nitrogenous tissues, as the muscle and bone, and supply the albuminoids of the milk and other fluids. The chief fuel ingredients of the food are the carbohydrates, such as sugar, starch and fiber, and the fats and oils. These are either consumed in the body to produce heat and muscular power or are stored up as fat.

Fuel Value.—The value of food as fuel may be measured by the amount of energy capable of being transformed into heat within the body. The unit of measure commonly used is the calorie. One calorie is approximately the amount of heat necessary to raise the temperature of a pound of water four degrees Fahrenheit. From experiment it has been estimated that a pound of protein or carbohydrates when burned in the body yields energy corresponding to about 1,860 calories; and a pound of fat about 4,220 calories.

Food for Maintenance and for Production.—The body requires a certain amount of food for maintenance. When a horse or a cow is at rest in the stall it is continually using its muscles and other tissues for respiration, for keeping the blood in circulation, and for other work within the body. In these ways the animal machinery is being constantly worn out and must be kept in repair. For this repair, this making up for constant waste, a certain amount of food is needed. The muscular work also requires power. The power comes from the burning of the food just as truly as the power that moves the locomotive comes from the coal that is burned in the furnace. The animal machine differs from the locomotive, however, in that it uses its own substance for fuel. But the material thus used must, of course, be replaced. The amount of building material needed to make up for the constant wear and tear of the animal machine is much larger than is the case with the locomotive. Finally, the body must be kept warm. This requires fuel also, and here again the food is the fuel.

If the horse is drawing a load it needs more food than if it is standing in the stable. It must have more protein to make up for the increased wear of the machinery, especially if

the work is severe; and more energy, that is, more fuel, for the extra work. In other words, when the horse is at rest in the stall it needs food only for maintenance, but when it is at work it requires an extra amount for production. So likewise the cow at rest in the stall needs food for maintenance, but when she gives milk she needs extra food to form the casein, fat, milk sugar, and other ingredients in the milk; that is, she must have increased food for production.

When an animal is fattened it needs food both for maintenance and for the production of extra flesh and fat. In fact whatever the form of production, whether it be work, milk, fat, or otherwise, food is required in addition to that necessary for maintenance. The same is true of the young, growing animal, which needs food for the material that is constantly being added to its body in growth.

When the animal has not food enough to supply its needs it draws upon the store previously accumulated in its body. When it has more than it needs it stores a part of the extra supply. The body is constantly storing up new material and consuming that which has been previously stored. The fuel of the body is stored in the form of fat which, as we have seen, is the most concentrated form of fuel for the use of the animal. But the body can store protein, carbohydrates, and other materials also, and what is more, it has the power of transforming one of these into the other. It can transform the sugar or starch of its food into fat, which it stores for future use, and it can also make fat from protein. But it cannot make protein of the fats or carbohydrates; protein contains nitrogen, of which the fats and carbohydrates have none. All of these classes of nutrients can be burned for fuel. The protein can thus do the work of the fats and carbohydrates, but these cannot take the place of the protein in building tissue, such as muscle, tendon, bone, etc., or form the nitrogenous material of the blood or milk. The albuminoids of milk, casein, and albumin, which contain nitrogen, are made from protein, but they cannot be made from carbohydrates and fats. It seems probable that the protein of which this casein and albumin are made is largely, if not entirely, that which has formed a part of the body, *i. e.*, of the lacteal glands. It has been believed also that body protein is transformed into milk fat, and it has

been lately indicated by a very interesting experiment conducted under the direction of Prof. W. H. Jordan at the New York State Experiment Station, that milk fat can be made from the carbohydrates of the food.*

Just how the different ingredients of the milk are formed and just what ingredients of the food or the body are used for their production, physiological science has not yet definitely told, although a great deal of valuable information has accumulated. The same is true regarding the formation of other materials in the body and the ways in which the different ingredients of the food are used for the purpose. But at the same time the amount of exact information we now have is very considerable.

One thing which feeding experiments and practical experience in feeding are bringing out very forcibly is the importance of fitting the food to the special needs of the animal for maintenance and for the kind of production demanded of it. For instance, a cow giving milk needs the different nutrients of her food in the proportion which will best serve for the maintenance of her body and for the making of milk. Her body may be regarded as a machine for manufacturing milk. It is a very delicate machine and requires a great deal to keep it running; that is, for maintenance, whether it is actually producing or not. For the manufacture of milk it needs raw material. This raw material, which is to be made into milk, is the same as the material used to keep the machine in repair and for fuel to keep it in motion. But this raw material consists of different kinds of ingredients—protein, fats, carbohydrates, and others, and if we are to get the largest and best product with the least costly raw material, and the least injury to the machine, the proportions must be fitted to the demands.

In thus fitting the food to the requirements of the cow it is necessary to have enough protein, because it has a special work to do for which no other of the nutrients will suffice. If we have too little of the fuel ingredients we can make up the deficiency with extra protein, but if the protein for building and repair and the production of the albuminoids of the milk is lacking no amount of other ingredients will take its place.

* New York State Experiment Station, Bulletin No. 132, On the Source of Milk Fat.

This is not the whole story, but it is practically all that is definitely known to-day, and much more than was known a few years ago. Physiologists know that food has very diverse functions. They believe that the protein compounds have other functions than those briefly stated above. It is thought that certain of the different substances which chemists group together under the general designation of protein, stimulate the bodily activities in various ways. Investigators are, indeed, able to demonstrate by actual experiments that different chemical compounds, which occur in foods and feeding stuffs, influence in widely different ways the health and strength of the animal and its capacity for production. Practical feeders understand perfectly well that success in the selection of feeding stuffs and the compounding of rations depends upon a great many other things than the proportions of nutrients as shown by the chemist's analyses. At the same time it is very important that the proportions of nutrients be properly fitted to the animal's needs, and here one most essential thing is the proportion of protein—the ratio of nitrogenous to carbonaceous nutrients.

Nutritive Ratio.—The effectiveness of a ration, then, depends not only upon the amount of digestible nutrients it supplies, but also upon the ratio of the tissue-forming substances to the fuel ingredients. This relation of the amount of protein to the amount of the carbohydrates and fats is expressed by the nutritive ratio. The fuel value of the fat is about two and one-fourth times that of the carbohydrates and protein. If the sum of the digestible carbohydrates and two and one-fourth times the digestible fat of the ration is divided by the amount of digestible protein, the quotient gives what is called the nutritive ratio.

Wide versus Narrow Rations.—In calculating the nutritive ratio the protein is taken as one; the carbohydrates and fat taken together may be four, six, eight, or otherwise, as the case may be. Where the proportion of fuel ingredients is large the ratio is said to be wide, where it is small the ratio is narrow. Some writers in estimating rations for milch cows consider a ratio above 1:6, *i. e.*, with more than six parts of fuel ingredients to one of protein as wide, and one with less than six of fuel

ingredients to one of protein as narrow. Thus rations of 1:6.5, 1:7, 1:9, and 1:12, that is, from 6.5 to 12 parts of fuel ingredients to 1 of protein would be wide, while ratios of 1:5.6, 1:4.5, or 1:4 would be narrow.

Most of the grasses, also corn fodders, corn silage, stover, oat hay, corn meal, etc., have relatively small quantities of protein, and hence have wide nutritive ratios, while the legumes, such as the clovers, alfalfa, vetch, peas, immature grasses, as rowen, and some milling products, are relatively rich in protein, and have narrow nutritive ratios.

Size of the Ration.—The total amount of the different nutrients fed makes up the size of the ration. This should be regulated by the weight of the animal and the amount of its product. In the current feeding standards, the size of the ration is commonly stated as so many pounds of digestible protein, fat, and carbohydrates per day per 1000 pounds of live weight. In feeding for milk, however, the quantity of that product given should regulate quite largely the size of the ration. A cow of 800 pounds live weight in the "flush," producing 30 pounds of milk per day, will often require a larger ration than a cow of 1000 pounds live weight, producing but 20 pounds of milk per day. The heavier ration may also be more profitable for the lighter animal while producing a large amount of milk.

NITROGENOUS FEEDING STUFFS FOR MANURE.

The value of nitrogenous feeding stuffs for manure is an important factor in their use. This is especially true in the older parts of our country where the fertility of soils has been reduced by long cropping. Nitrogen is the most expensive ingredient in the fertilizers we purchase. It costs three or four times as much per pound as potash, and two and one-half or three times as much as phosphoric acid.

The real value that the farmer is able to get out of his fodders in the form of manure depends upon the composition of the fodder, the kind of animal, the use to which the animal puts its food, and, most of all, the way in which the manure is cared for. The leguminous coarse fodders, such as clover, vetch, and peas, have a much higher manurial value than similar fodders of the grasses, corn stover, corn fodder, etc. Based upon the trade values of fertilizing ingredients used by

the Connecticut and other experiment stations in 1897, such fodders as clover hays, for instance, have a value for making manure nearly twice as great as the hays of our common grasses; while Chicago gluten meal, the old and new process linseed meals, and cotton seed meal are two and one-half to three times as valuable as corn meal. These figures are based upon the fertilizing value of the different feeding stuffs in their natural condition before feeding.

The amount and proportion of the fertilizing ingredients that the animal removes from the fodder depends largely upon the animal and way in which it uses its food. Young growing animals, for example, require a large amount of protein for the building up of muscle, and considerable phosphoric acid for the formation of bone. In the case of mature animals that are being fattened, nearly the whole of the fertilizing value of the fodder is returned in the manure. It has been found that in feeding milch cows as much as twenty-five per cent. of the fertilizing value of the food may be used by the animal, leaving about seventy-five per cent., or perhaps more, to be returned as manure. The actual proportion of this that the farmer really saves varies in accordance with the care bestowed upon the manure. In many stables the amount of waste, especially of the liquid manure, is very great. By the use of absorbents and the prevention of hot fermentation nearly the full value of the manure as voided by the animal may be retained. By making liberal use of feeding stuffs rich in nitrogen (protein), in our feeding practice, the fertilizers purchased for use on the farm may consist mainly of materials furnishing phosphoric acid and potash. Nitrogen can be obtained in the manure in no way more cheaply than by feeding it liberally to good stock, from which a fair profit is realized. The nitrogen and other fertilizing ingredients not used by the animal are left upon the farm as cheap by-products for use in growing crops.

In the following table will be found the percentages of nitrogen, phosphoric acid, and potash found in a number of our common feeding stuffs, and the valuation per ton based upon the trade values of the ingredients (nitrogen, phosphoric acid, and potash), as estimated by the experiment stations of New England, and used by them in the valuation of fertilizers for 1897. In the last column of the table is also given the assumed

manurial value after feeding, based upon the assumption that in feeding milch cows about seventy-five per cent. of the full fertilizing value of the feed is returned in the manure.

Composition and valuation of feeding stuffs as sources of fertilizing materials.

Feeding Stuffs.	Fertilizing Ingredients.			Valuation Per Ton.*	Assumed Manurial Value Per Ton After Feeding.†
	Nitrogen.	Potash.	Phosphoric Acid.		
Green Fodders.	Per Cent.	Per Cent.	Per Cent.	Dols.	Dols.
Flat pea, - - -	1.1	.5	.1	3.19	2.39
Cow pea, - - -	.3	.2	.1	1.00	.75
Soy bean, - - -	.8	.7	.2	2.75	2.06
Vetch, - - - -	.4	.5	.1	1.51	1.13
Corn silage, - - -	.4	.4	.1	1.42	1.06
Cured Fodders.					
Red clover, - - -	2.0	2.1	.4	7.09	5.32
Rowen, - - - -	1.7	1.6	.5	6.02	4.51
Vetch and oats, - -	1.2	1.3	.6	4.65	3.49
Hay, mixed, - - -	1.3	1.5	.3	4.77	3.58
Corn stover, - - -	.9	1.2	.3	3.54	2.65
Milling and By-Products.					
Corn meal, - - -	1.9	.3	.7	5.53	4.15
Soy bean meal, - -	5.9	2.2	1.6	17.74	13.30
Pea meal, - - -	3.1	1.0	.8	9.14	6.85
Buffalo gluten feed, -	3.7	.1	.3	9.27	6.95
Chicago gluten meal, -	6.0	.1	.4	14.89	11.17
Wheat bran, - - -	2.4	1.4	2.1	9.12	6.84
Wheat middlings, - -	2.8	.8	1.3	8.74	6.55
Cotton seed meal, - -	6.7	1.8	2.5	20.20	15.15
O. P. linseed meal, -	5.4	1.2	1.8	15.84	11.88
Cleveland linseed meal N.P.	5.8	1.3	1.7	16.79	12.59

* Based upon the trade values of fertilizing materials for 1897: Nitrogen, 12 cents; potash, 4½ cents; and phosphoric acid, 5 cents.

† Assuming that 75 per cent. of the original value is returned in the manure.

THE INFLUENCE OF FOOD UPON THE COMPOSITION OF COW'S MILK.

Practical dairymen have quite generally held to the belief that the "quality" of milk, meaning by quality the percentage of fat, is largely influenced by the kind of food eaten by the cow. Many practical feeders hold that by feeding, for example, considerable quantities of cotton seed meal, or by turning the cows on to a field of clover, they can produce not only larger quantities of milk, but larger quantities of cream and butter. How the milk changes with change of food is a matter about which the opinions of such feeders are less clearly

defined. Some would maintain that the milk yield simply increases or decreases in total amount while the composition remains the same. Others urge that by changing the feed the cow may be made to give not only more milk, but richer milk, *i. e.*, milk which will yield more cream and butter per quart. How the milk is richer, *i. e.*, whether the percentage of total solids is increased while the composition of the latter, the ratio of fat to casein and other ingredients, remain the same, or whether there is a one-sided increase of fat, is a further question about which there is much difference of opinion. But there are certainly many close observers who believe from what they see in their experience that it is possible to increase the fat in the milk by feeding without increasing the other milk solids in like degree.

On the other hand, the tendency among the most painstaking experimenters in this country, as in Europe, has been rather toward the belief that, with occasional exceptions, the composition of the milk is but little influenced by the kind of food, provided a sufficient total quantity of nutrients is fed to meet the requirements of the animal and the nutritive ratio is kept within reasonable limits—that, in other words, the breed and individuality of the cow rather than her food decide the composition of the milk. This latter view has been strongly maintained by German experimenters as the result of a long series of experiments with cows which were fed on different rations. It has been adopted by many students of the subject, although with a degree of reserve. Of late considerable attention has been given to the matter in some of its especial phases. The questions are still unsettled, but fortunately definite information is being gathered which will in time bring the certainty that is so much to be desired.

The following is from a review of the subject made over twenty years ago:*

"The general plan [of the experiments] is to feed cows for a period of two or three weeks or so, with a certain ration, and then to alter the latter so as to make it larger or smaller, or to put in more fatty matters and less protein, more protein and less fat. The fodder and milk are both measured and analyzed. A large number of such feeding-trials have been carried on by Kühn, Wolff, Fleischer, Stohmann, and others. As the result of several series of experiments, continuing

* In an address on Results of Late European Experiments on the Feeding of Cattle, before the Connecticut Board of Agriculture, by W. O. Atwater. Report of the Board for 1874, p. 184.

through several months, conducted with the greatest accuracy, and involving many hundreds of analyses of fodder and milk, Kühn concludes that, as soon as the amount of the ration exceeds a certain maximum, an increase is without effect upon the quality, and exercises only a slight influence upon the quantity of the dry substance of the milk produced.

"This principle, first enunciated by Kühn, has been confirmed by several experiments of similar character made by Wolff and Fleischer. Without going into details I will simply say that as the result of all their work these different experimenters come to about this conclusion.

"By increasing the ration up to a certain point the yield of milk may be increased, and not only the total yield but also the richness of the milk, the amount of dry substance, fat, casein, sugar, etc., may be thus increased. But at the same time the composition of this dry substance, the relative percentages of fat and casein remain the same even though the proportion of fat or albuminoids in the food may be changed.

"It is very important, however, to notice that the amount of milk yielded and the variations produced by the food differs greatly with different breeds and individuals. That is to say, if I am feeding my cow a moderate ration, I may by adding thereto get more quarts of milk per day, and more casein and butter in a quart. But I may not expect to get a one-sided increase of butter by using oily food, or of casein by using more nitrogenous ration. When the fat is increased or decreased the casein changes in like proportion.

"These results are very easily explained by the theory of the formation of the milk, lately propounded by the well-known physiologist Voit. This theory, which seems quite well supported by facts, assumes that the milk is not merely filtered from the blood through the lacteal glands, but is rather a product of a metamorphosis of the glands themselves. 'The milk' says Voit, 'is essentially this organ liquefied by fatty degeneration.'

"In this view, it is easy to see that when the cow is well fed and in good condition, there will be plenty of food for the formation of lacteal glands, and hence a plentiful production of milk, and that the composition of these would not be easily affected by variation of the composition of the food within ordinary ranges; and hence, why it should be so difficult by changes in the food to effect any change in the composition of the organic substance of the milk. Still it does not appear to be proven that a change in the quality of the food may not, in the course of months or years, or with the progeny, change the composition of the organic substance of the milk.

"There are, it is true, some exceptions to this rule. Some kinds of oily food have been observed to produce milk richer in fat. Indeed temporary changes in the composition of milk often follow changes in the food. But when experiments are repeated and long continued, and when the milk is subjected to repeated and rigid analysis these changes are generally found to disappear.

"As regards the effect of different foods on the composition of the milk we may not hope by variation in the fodder to change a 'casein (cheese) cow' to a 'butter cow.' We must rather depend for the quality of the milk, the relative richness in fat or casein, its special fitness for butter-making or cheese-making, upon the peculiarities of different breeds or different individuals, and for quantity upon the peculiarities of the animals themselves. Or, in few words, for quality of milk, select proper breeds; for quantity, good milkers."

The uncertainty which was indicated in the statements just quoted and which still exists in the minds of many experimenters is expressed by Prof. Soxhlet of the Experiment Station at Munich, Germany, who has been lately experimenting upon the subject. The following is a brief *résumé* of Prof. Soxhlet's statements and experiments:*

"As compared with feeding hay alone, hay and an easily digestible carbohydrate gave a milk poorer in fat. When the hay ration remained practically the same, but large amounts of starch were fed in addition, there was no appreciable increase in the milk yield, but a noticeable decrease (about .7 per cent.) in the fat. Fourteen pounds of starch was fed with sixteen pounds of hay, the starch being treated with malt and given as a sweet drink. The starch is probably changed to body fat, but not to milk fat.† This agrees with the investigations of Kühn and Stohmann. Likewise, increasing the amount of protein in the food resulted in an increase in the milk production or prevented a shrinkage with advancing lactation, but gave no one-sided increase in the fat content. The fat content was practically the same when 4 pounds of rice gluten containing 71 per cent. of protein was fed as when hay was fed alone. The addition of fat to hay materially increased the fat content of the milk, provided the fat was in form to be taken up and digested. When sesame oil, linseed oil, or tallow was added to the ration, in the form of emulsions thoroughly mixed with the drinking water, the milk contained as high as 5.8 per cent. of fat. When 1.5 to 2 pounds of linseed oil was added to 18 to 22 pounds of hay the milk averaged 5.24 per cent. of fat for 4 days; when 1 to 2 pounds of tallow was added to the same amount of hay the milk contained from 4.24 to 5.5 per cent. of fat, the average for 8 days being 4.7 per cent.

"This is contrary to the results of experiments by M. Fleischer, G. Kühn, and Stohmann. In the latter cases the addition of oil resulted in a slight decrease in the fat, while in the present case it resulted in a material increase in the fat content of the milk. This may be explained by the fact that formerly the oil was mixed with the fodder, in which form it is not digested and causes a disturbance of the digestive functions.

"In Fleischer's experiment the addition of 4 pounds of flax seed resulted in no increase in milk fat, because the fat is not digested from whole flax seed. But in Stohmann's experiment, in which ground flax seed extracted of fat was fed in place of fat linseed cake, the fat content of the milk decreased from .6 to 1 per cent. This is believed to furnish a striking illustration of the effect of a ration poor in fat as compared with one rich in fat. This experiment, made in 1866, has previously been overlooked in discussing this question.

"In feeding a ration rich in fat the author believes that the increase in fat content of the milk does not take place by a transmission of the fat of the food to the milk. With such feeding the content of volatile fatty acids in the milk fat decreased in some cases nearly one-half. For instance, the Meissl number dropped from 25.32 to 15.7 when 16 pounds of hay and 2 pounds of sesame oil

* Experiment Station Record, Vol. VIII., p. 1016.

† The late experiments by Prof. Jordan and his associates at the New York State Experiment Station, referred to on page 89, imply that milk fat is formed from the carbohydrates of the food.

were fed; and the fat in the milk from cows which were fed 60 to 65 liters of corn-distillery slop showed only 15.5 per cent. volatile fatty acids. From this it might be concluded that the sesame oil and corn oil, which are nearly free from volatile fatty acids, were transmitted to the milk; but if this had been the case the melting point of butter made from this milk would have been materially decreased. On the contrary, it was considerably increased, being 41.5°, as compared with the average melting point of butter of 36°, while that of the oils is below 0°.

"As the result of the author's experiments, as well as of the examination of milk from herds to which large amounts of corn-distillery refuse or the residue from the manufacture of starch from corn were fed, it was found, as a rule, that food rich in oil did not give, as was expected, a milk fat with a low melting point, but instead one with an uncommonly high melting point. In other words, such food did not give a soft butter, as is generally stated, but a hard butter instead.

"The fat of the food does not go directly into the milk, but forces into the milk body fat, *i. e.*, tallow, and thus indirectly increases the quantity of milk fat. Normal butter fat is certainly a product of the activity of the lacteal glands. Its amount can, therefore, not be materially increased by the manner of feeding without increasing the secretion of milk as a whole. Unlike the carbohydrates and protein, the fat of the food can materially increase the fat content of the milk, but only by the body fat produced from the carbohydrates being transported to the milk, whereby the fat of the food is probably consumed to keep up the oxidation in place of the body fat.

"From the results obtained the author believes that in purchasing concentrated feeding stuffs for cows special weight should be laid upon high fat content. While at present the protein is rated in Germany at about one and a half times the money value of fat, in future the fat of concentrated feeding stuffs will be considered of at least equal value to protein, and probably of higher value. In concentrated feeding stuffs the fat should be guaranteed separately. The oil factories should be induced to furnish oil cakes with a higher fat content, as was formerly the case before the methods of extraction were perfected.

"These facts, the author believes, throw a new light upon the secretion of milk, furnishing a further ground for the belief that the constituents of milk result from the breaking down of organized tissue. On a ration poor in fat the milk fat is newly formed fat of a special kind, distinguished from other animal and plant fats by its higher content of volatile fatty acids. On a fat-free ration only this 'normal' fat (*i. e.*, that resulting from the breaking down of milk-produciug tissue) can appear in the milk, and its amount cannot be increased by adding fat-producing nutrients (carbohydrates) or protein to the food. Fat-free food can increase the production of milk fat only by increasing the tissue which yields milk by decomposition, in which case the other milk constituents are increased in the same proportion as the fat. The feeding of large amounts of carbohydrates can increase the body fat, but not the milk fat, since they do not contribute to the formation of milk-producing tissue; when fed in large quantities with a ration which is not rich in protein, as hay, they decrease the fat content of the milk, because they diminish the proportion of protein in the ration—that is, the tissue-forming material (glandular tissue and white blood corpuscles).

The fat of the food alone is capable of bringing about a one-sided increase in the fat content of the milk; it causes a transmission of the body fat to the milk without itself going into the milk The greater the fat content of the food the larger the proportion of milk fat which is derived from the body fat—that is, tallow; and in the same proportion, as a rule, the lower the content of volatile fatty acids in the milk fat the higher its melting point."

EXPERIMENTS ON THE EFFECTS OF WIDE AND NARROW RATIONS, OR SMALL VERSUS LARGE PROPORTIONS OF NITROGENOUS NUTRIENTS.

A large amount of experimenting has been carried on by the experiment stations of this country for the purpose of studying the effect of different rations on the quantity and quality of milk, and upon the financial results obtained from the use of different feeding stuffs. An effort is here made by one of the writers (C. S. P.), to summarize such of these experiments as have been made with widely varying quantities of protein (narrow and wide rations) where sufficient data are given to make it practicable to estimate the rations, and to study their effect on the quantity and composition of the milk. Several of these experiments were conducted for the express purpose of studying the effects of wide and narrow rations, and all of the conditions other than the one being studied seem to have been carefully controlled and made as uniform as possible throughout the experiment. In other cases the object in view has been simply to study the relative profit from the use of feeding stuffs varying widely in composition. In some cases analyses of the feeding stuffs were not made, while in the majority of cases the digestibility of the ration was calculated from average digestion coefficients. A considerable number of such experiments are summarized in table 13, on pages 102, 103. Only experiments showing widely varying quantities of protein in the rations have been tabulated. In most cases the quantity of digestible protein fed daily in the narrow ration was about twice that which was fed in the wide ration.

*Experiments at the Iowa Experiment Station.**—Perhaps the most notable instance of the apparent effect of food on the quality of the milk, in the experiments tabulated, is that brought out by those made at the Iowa Station. The results are summarized by the writers of the Bulletin as follows:

* Bulletin 14, August, 1891.

"1. The kind of food had a decided and material effect upon the quantity of milk produced as regards percentage of fat and solids. The rations compared produced an average difference of over one-half a pound of fat and nearly three-quarters of a pound of solids per 100 pounds of milk.

"2. Change of feed influenced the quality of the milk considerably more than it did the quantity. Where one ration produced twenty-seven per cent. more butter-fat (gross yield) than the other, the increase in milk flow was only eight per cent. Two-thirds of the increase in gross yield of butter-fat was due to improved *quality* of milk, and only one-third to increased *quantity*.

"3. The ratio of fat to 'solids not fat,' was considerably modified by change of feed. Under one feed (wide ration) the ratio averaged 396:1000, and under the other (narrow ration) 457:1000."

Four cows varying in live weight between 875 and 1150 pounds were used. All of the cows had calved within six weeks previous to the beginning of the experiment. The daily rations per cow during periods 1 and 2 were as follows:

PERIOD 1. *Corn and Cob Meal Ration.*	PERIOD 2. *Sugar Meal (Gluten Feed) Ration.*
12¼ pounds corn and cob meal.	10 pounds sugar meal.
12 pounds corn fodder.	12 pounds corn fodder.
2 pounds clover hay.	4 pounds clover hay.

"For period 3 the corn and cob meal was increased to 13 pounds, to give that feed a greater advantage; otherwise the amounts remained the same as in periods 1 and 2."

The feeding periods covered twenty-one days each. The rations were fed for a week before the beginning of period 1, and an interval of ten days was allowed between the periods for changing the feed, and to allow the cows to become accustomed to the new feed before the regular feeding period was begun. The cows were fed in pairs. Lot A, two cows, had the corn and cob meal ration (wide), during period 1; the sugar meal ration (narrow), during period 2; and the corn and cob meal again in period 3. Lot B, two other cows, had the same feeds in the reverse order, sugar meal (narrow) ration first, then corn and cob meal (wide), and for the third period sugar meal. The results with the narrow and wide rations for the two lots of cows of two each have been summarized in table 13. The rations have been calculated by the writer from the actual amounts of food eaten during the period of twenty-one days.

In these calculations the composition of corn and cob meal, and of the sugar meal, was taken as given in the report of the experiment. The composition of other feeds used was assumed

from tables of average composition of feeding stuffs. Average factors of digestibility from American digestion experiments were used in all cases. The quantity of protein in the narrow rations (2.37 pounds per day) is about double that contained in the wide rations (1.16 pounds per day). In the case of both lots of cows the narrow rations gave a considerable increase of milk, amounting to an average of 1.4 pounds per day in the case of lot A, and 2.6 pounds in the case of lot B, while the average percentages of fat for both lots of cows were about six-tenths higher in the case of the cows fed the narrow rations. The exact figures are: Lot A, wide ration, 3.40 per cent.; narrow ration, 3.98 per cent.; and lot B, wide ration, 3.33 per cent.; and narrow ration, 3.92 per cent. The proportion of fat in the total solids was also considerably greater in the case of the cows fed the narrow rations. In the case of lot A the fat was 28.7 per cent. of the total solids for the wide ration and 32.0 per cent. for the narrow ration; and in the case of lot B 27.6 per cent. for the wide and 30.8 per cent. for the narrow ration.

*Experiment at the Maine State Experiment Station.**—Prof. W. H. Jordan has reported experiments on the effect of wide and narrow rations with three cows. He writes:

"The experiment with cows, the results of which are given in this connection, was planned with references to changes in the ration so radical as to induce if possible, corresponding variations in the milk. * * * The rations in this experiment were made to differ very widely in the relation of the nitrogenous to the non-nitrogenous nutrients."

The experiment was begun with four cows, but one was dropped out and results are reported from only three. The three feeding periods covered thirty-five days each. The first week of each period was omitted from the final results. The milk was analyzed for the last five days of each period. The two rations compared were as follows:

RATION 1.

Timothy hay,	As much as the cow would eat.
Corn meal,	2 pounds.
Cotton seed meal,	2 pounds.
Gluten meal,	2 pounds.

RATION 2.

Timothy hay,	As much as the cow would eat.
Corn meal,	6 pounds.

* Maine Experiment Station, Report, 1893.

Ration 1 was fed to cow A during the first and third periods, and to cows R and L T during the second or middle period. Ration 2 was fed to cow A in the middle period, and to cows R and L T in the first and third periods. The average rations fed, as taken from the report of the experiment, are shown in table 13, and also the effect of the rations on the quantity of milk, butter-fat, and solids, and on the percentages of fat, solids, and solids not fat. From this table it will be seen that with the narrow ration the daily milk flow ranged from 3 to 5½ pounds per day greater than with the wide rations, while the percentages of fat in the milk ranged from .3 to .5 of a per cent. higher when the narrow rations were fed. The proportion of fat in the total solids was also greater in the case of the narrow rations. Cow A for the narrow ration gave 33.4 per cent. of fat in the total solids, and for the wide ration 31.7 per cent. Cow R gave 34.3 per cent. for the narrow ration and 32.7 per cent. for the wide, while cow L T gave 33.1 per cent. for the narrow and 31.6 per cent. for the wide ration.

*Experiment at the Pennsylvania State College Experiment Station.**—An experiment on the "Influence of Nutritive Ratio Upon the Economy of Milk and Butter Production" is reported by the Pennsylvania Station. Nine Guernsey and grade Guernsey cows, about sixty days past calving, were fed through four periods of thirty days each. The rations fed were as follows:

Period 1. Grain mixture of gluten feed and chopped wheat; coarse fodder, corn stover. Digestible nutrients consumed daily per cow, 11.58 pounds; digestible protein, 1.52 pounds; nutritive ratio, 1:6.6.

Period 2. For the gluten feed the same quantity of cotton seed meal was substituted; the coarse fodder remained unchanged. Digestible nutrients consumed daily per cow, 12.87 pounds; digestible protein, 2.62; nutritive ratio, 1:3.9.

Period 3. Old process linseed meal was substituted for cotton seed meal. Digestible nutrients consumed per cow daily, 12.74 pounds; digestible protein, 2.38 pounds; nutritive ratio, 1:4.4.

Period 4. Gluten feed and chopped wheat as in period 1; digestible nutrients consumed per cow daily, 11.64 pounds; digestible protein, 1.52 pounds; nutritive ratio, 1:6.7.

* Report, 1895.

TABLE 13.—PART I.

Feeding stuffs used in experiments with wide and narrow rations.

Location of Experiment.	Number of Cows and Kinds and Amounts of Feeds used per Cow per Day. Weights in Pounds.	Average Weight of Cows.	Weight of Dry Matter fed per Cow per Day.
		Lbs.	Lbs.
Experiments at Iowa Station.[1]	Cows 21 and 22. Wide ration. Periods 1 and 3, -	1050	—
	Corn fodder, 10.2; clover hay, 4.0; corn and cob meal, 12.5,	—	22.7
	Cows 21 and 22. Narrow ration. Period 2, - -	1050	—
	Corn fodder, 10.0; clover hay, 4.0; sugar meal, 10.0,	—	21.1
	Cows 33 and 65. Wide ration. Period 2, - -	960	—
	Corn fodder, 9.6; clover hay, 4.0; corn and cob meal, 12.3,	—	22.0
	Cows 33 and 65. Narrow ration. Periods 1 and 3,	960	—
	Corn fodder, 9.8; clover hay, 4.0; sugar meal, 10.0,	—	20.9
Experiments at Maine Station.[2]	Cow A. Wide ration. Period 2, - - - -	870	—
	Timothy hay, 21.0; corn meal, 6.0, - - - -	—	23.8
	Cow A. Narrow ration. Periods 1 and 3, - -	860	—
	Tim. hay, 22.2; corn meal, 2.0; glu. meal, 2.0; cot. meal, 2.0,	—	24.8
	Cow R. Wide ration. Periods 1 and 3, - - -	850	—
	Timothy hay, 21.3; corn meal, 6.0, - - - -	—	24.0
	Cow R. Narrow ration. Period 2, - - - -	855	—
	Tim. hay, 22.0; corn meal, 2.0; glu. meal, 2.0; cot. meal, 2.0,	—	24.7
	Cow L. T. Wide ration, Periods 1 and 3, - -	850	—
	Timothy hay, 20.4; corn meal, 10.0, - - -	—	23.6
	Cow L. T. Narrow ration. Period 2, - - -	835	—
	Tim. hay, 22.0; corn meal, 2.0; glu. meal, 2.0; cot. meal, 2.0,	—	24.7
Experiments at Penna. Station.[3]	Nine cows. Wide ration. Periods 1 and 4, - -	800	—
	Corn stover, 7.6; chopped wheat, 6.0; Buffalo gluten, 5.1, - - - - - - - - - -	—	14.6
	Nine cows. Narrow ration. Periods 2 and 3, - -	790	—
	Corn stover, 9.3; chopped wheat, 6.3; period 2, cotton seed meal, 5.3; period 3, O. P. linseed meal, 6.0, - - - - - - - - - -	—	16.3
Experiments at Mass. State Sta.[4]	Six cows. Narrow ration. Series Ia, - - -	880	—
	Silage, 43.7; corn stover, 4.0; cotton seed meal, 3.0; Buffalo gluten, 3.0; wheat bran, 3.0, - - -	—	20.4
	Six cows. Wide ration. Series Ib, - - - -	865	—
	Sil., 43.6; corn stover, 4.0; corn meal, 4.5; wheat bran, 4.5,	—	20.0
	Six cows. Narrow ration. Series IIa, - - -	870	—
	Silage, 43.0; corn stover, 4.0; cotton seed meal, 3.0; Buffalo gluten, 3.0; wheat bran, 3.0, - - -	—	20.7
Experiments at Mass. (Hatch) Station.[5]	Six cows. Wide ration. Period 1, - - - -	940	—
	Hay, 16.2; sug. beets, 12.0; wheat bran, 3.0; corn meal, 5.9,	—	23.6
	Six cows. Narrow ration. Period 1, - - -	940	—
	Hay, 15.2, sug. beets, 12.0; wheat bran, 3.0; Chic. glu. 5.9,	—	22.7
	Six cows. Wide ration. Period 2, - - - -	890	—
	Hay, 10.1; millet and soy bean silage, 28.3; wheat bran, 1.9; corn meal, 5.8, - - - - -	—	21.2
	Six cows. Narrow ration. Period 2, - - -	900	—
	Hay, 10.1; millet and soy bean silage, 28.3; wheat bran, 2.8; Chic. glu., 3.0; O. P. linseed, 1.9, -	—	21.6

[1] See page 98. [2] See page 100. [3] See page 101. [4] See page 105. [5] See page 106.

TABLE 13.—PART II.

Quantity and composition of milk in experiments with wide and narrow rations.—(See opposite page.)

Ration.		Digestible Nutrients. Protein.	Fat.	Carbo-hydrates.	Nutritive Ratio.	Average Daily Yield of Milk.	Average Per Cent. of Fat.	Average Daily Yield of Fat.	Average Per Cent. of Solids.	Average Daily Yield of Solids.	Per Cent. of Fat in Total Solids.	Aver. Per Cent. of Solids not Fat.
		Lbs.	Lbs.	Lbs.	1:	Lbs.	PerCt.	Lbs.	PerCt.	Lbs.	PerCt.	PerCt.
1	Wide,	1.17	.43	14.28	13.0	27.6	3.40	.94	11.86	3.27	28.7	8.46
	Nar.,	2.38	1.11	11.55	5.9	29.1	3.98	1.16	12.45	3.62	32.0	8.47
	Wide,	1.15	.43	13.82	12.9	23.3	3.33	.78	12.07	2.81	27.6	8.74
	Nar.,	2.36	1.11	11.31	5.9	25.9	3.92	1.02	12.72	3.29	30.8	8.80
2	Wide,	1.18	.63	13.0	12.3	20.0	4.24	.85	13.39	2.68	31.7	9.15
	Nar.,	2.09	.84	12.2	6.7	25.6	4.72	1.21	14.12	3.61	33.4	9.40
	Wide,	1.18	.73	13.0	12.3	15.2	4.46	.68	13.65	2.07	32.7	9.19
	Nar.,	2.09	.84	12.1	6.7	20.7	4.77	.99	13.92	2.88	34.3	9.15
	Wide,	1.17	.62	12.8	12.2	15.8	4.27	.67	13.50	2.13	31.6	9.23
	Nar.,	2.09	.84	12.1	6.7	19.1	4.72	.90	14.27	2.73	33.1	9.55
3	Wide,	1.52	.57	8.83	6.7	15.0	4.48	.67	13.57	2.04	33.0	9.09
	Nar.,	2.50	.72	8.69	4.2	15.7	4.94	.78	14.25	2.24	34.7	9.31
4	Nar.,	2.58	1.10	9.63	4.7	21.0	4.60	.97	13.71	2.88	33.6	9.11
	Wide,	1.31	.69	11.32	9.8	18.9	4.16	.77	13.48	2.55	30.9	9.32
	Nar.,	2.55	1.08	9.64	4.7	19.0	4.81	.91	13.80	2.63	34.8	8.99
5	Wide,	1.46	.52	12.45	9.4	23.7	4.47	1.06	13.56	3.21	33.0	9.09
	Nar.,	3.07	.59	10.23	3.9	27.2	4.51	1.23	13.66	3.72	33.0	9.15
	Wide,	1.45	.54	11.44	8.9	22.9	5.02	1.15	14.12	3.23	35.6	9.10
	Nar.,	2.85	.65	9.96	4.0	25.9	4.83	1.35	13.83	3.58	34.9	9.00

The feeding experiment extended from November 20 to March 20. It included four periods of thirty days each, and all of the cows (9) were fed a uniform ration during each of the periods. The herd had a wide ration during the first and the last periods, while the rations for the two intervening periods were narrow. The average of the rations actually eaten in periods 1 and 4, and in periods 2 and 3, will be found in table 13. From this it will be seen that the narrow rations averaged about two and one-half pounds of digestible protein per day, while the wide ration contained about one and one-half pounds. In this table the effect of the two rations on the yield of milk, butter-fat, and solids, and on the percentages of fat, solids, and solids not fat is also summarized. The average daily yield of milk for the nine cows during periods 1 and 4 (wide rations) was 15.0 pounds, and for periods 2 and 3 (narrow rations), 15.7 pounds. The average percentage of fat in the milk was 4.48 per cent. for the wide rations, and 4.94 per cent for the narrow rations. The proportion of fat in the total solids was also increased when the narrow rations were fed. In the following table, taken from the report of this experiment, are given the average composition of the milk of all the cows for each period, and the proportion of fat in the total solids.

Results of cow feeding experiments by the Pennsylvania Station.

Period.	Protein in Food.	Nutritive Ratio of Food.	Fat.	Total Solids.	Per cent. of Fat in Total Solids.	Nitrogen.
	Lbs.		%	%	%	%
1. Wide, - - - -	1.52	1:6.6	4.09	13.11	31.01	.560
2. Narrow, - - -	2.62	1:3.9	4.74	14.01	33.63	.593
3. Narrow, . - - -	2.38	1:4.4	5.13	14.49	35.26	.617
4. Wide, - - - -	1.52	1:6.7	4.87	14.02	34.56	.602
Average of 1 and 4 (wide), -	1.52	1:6.65	4.48	13.56	32.79	.580
Average of 1 and 3 (narrow),	2.50	1:4.15	4.98	14.25	34.45	.605

"From the table it appears that the narrower nutritive ratios tended to increase the per cent. of fat, of total solids, and of nitrogen, and the proportion of total solids that are fat. * * * * * The fat content of the milk increased more rapidly when narrow nutritive ratios were fed than did the other solids."

*Experiments at the Massachusetts (State) Agricultural Experiment Station.**—Six cows were fed in groups of three each, alternating between narrow and wide rations. The narrow rations contained about 2.60 pounds of digestible protein per day, and the wide ration 1.30 pounds per day. Other rations were fed later in the experiment, but for the present purposes comparison has been made only between three rations, two narrow and one wide. The cows were fed in two lots of three each, during periods of fourteen days. Cows 1, 2, and 3, were fed the narrow ration while cows 4, 5, and 6 were having the wide ration; afterwards cows 4, 5, and 6 received the narrow ration while cows 1, 2, and 3 had the wide ration. The average narrow rations fed the six cows, Series I. *a* and Series II. *a*, are shown in table 13, together with the intervening wide ration, Series I. *b*. The average results on the yields of milk, butter-fat, and solids, and the percentages of solids, fat, and solids not fat, are also shown in the same table. It will be noticed that in the first two series of the experiment, when the animals passed from a narrow ration to a wide ration, there was a decided falling off in the milk flow, 21.0 to 19.0 pounds per day per cow, while the narrow ration, Series II. *a*, which was fed when the cows were considerably farther along in the period of lactation, seemed to check the decline in the milk flow. The average percentages of fat for the six cows while the first narrow ration was being fed (period 1) was 4.60 per cent.; for the wide ration (period 2), 4.16 per cent.; and for the narrow ration which was fed later (period 3), 4.81 per cent. The average percentage of fat in the total solids of the milk was 34.1 per cent. while the narrow rations were fed, and 30.9 per cent. while the wide rations were fed. Dr. J. B. Lindsey, who conducted and reported the experiment, says in his summary as follows:

"The experiment certainly indicates that rations so put together as to contain 2.5 to 3.5 pounds digestible protein, can be fed with greater profit to the farmer than rations containing 2 pounds."

"The milk was principally affected in the first series, when the change from 1.5 to 3 pounds of digestible protein (per thousand pounds live weight) was made. If the change had been more gradual, it is possible but little change in the milk would have been noted."

* Twelfth Annual Report, 1894.

*Experiments at the Massachusetts (Hatch) Experiment Station.**—The experiments, two in number, made under the direction of Dr. J. B. Lindsey, were conducted during the autumn and winter of 1895-96. Six cows were used. They were divided into two lots. The division was such as to make the productive capacities of the two lots as nearly alike as possible. During the first half of each experiment, three of the cows were fed the narrow ration, while the other three were receiving the wide ration. In the second half of the experiment, the order was reversed. In the first experiment the two periods were twenty-six days each, and at least seven days were allowed after the animals were placed upon the full ration, before the actual test was begun. In experiment 2 the periods were twenty-one days each. The milk was analyzed from composite samples taken for five days of each week during the several periods. The wide and narrow rations as taken from the report of the experiment are shown in table 13. While the yield of milk obtained from the use of the narrow rations was much larger, the percentages of fat do not seem to have been materially affected by the rations. The following is taken from the summary of the results as given in connection with the report of the experiment:

"The same amount of digestible matter in narrow rations produced from 11.8 to 12.9 per cent. more milk than a like amount of digestible matter in wide rations; narrow rations also reduced the cost of production from 5 to 12 per cent."

"The average cost of a quart of milk produced with the narrow rations was 1.81 cents, and with the wide rations 1.97 cents."

"The narrow rations produced over the wide rations practically the same relative increase in the amount of butter, and the same decrease in the cost of production as in the case of the milk."

"Neither the narrow nor the wide rations produced any decided change in the composition of the milk."

Experiments at the Vermont Experiment Station.†—Accounts of several experiments on the effects of by-products from corn (gluten meal, gluten feeds, etc.), as compared with corn meal and wheat bran in feeding milch cows are given. The kinds and quantities of the various coarse feeds used in the several trials varied considerably, and for this reason it is impossible to compare the results strictly on the basis of the proportions of protein fed. In all cases, however, the quantities of gluten

*Annual Report, 1897.

†Sixth Annual Report and Bulletin 48.

meal or gluten feed used were relatively large, so that as nearly as can be estimated, the narrow rations in the trials where cream gluten and King gluten meals were fed, contained about twice as much digestible protein per day as the wide rations (corn meal and wheat bran). In the majority of cases, there was a decided increase of milk from the use of the narrow ration. This was especially true where the narrow rations were made up of the more highly nitrogenous by-products, such as cream and King gluten meals. The effects of the rations showing the greatest range in the proportions of protein fed on the percentages of solids and fat, and the ratio of fat to solids not fat will be seen in the following table:

Results of cow feeding experiments by the Vermont Station.

MEAL.	Kind of Ration.	No. of Cows.	Total Solids in Milk.	Fat in Milk.	Solids not Fat in Milk.	Ratio of Fat to Solids Not Fat.
			%	%	%	
Bran and corn, - - -	Wide.	3	13.84	4.53	9.31	1:2.06
Cream gluten meal, - -	Narrow.	3	14.10	4.90	9.20	1:1.88
Bran and corn, - - -	Wide.	7	13.88	4.69	9.19	1:1.96
King gluten meal, - - -	Narrow.	7	13.89	4.82	9.07	1:1.88

The following summary of results is taken from the bulletin referred to:

"The average results all agree in showing a higher per cent. of fat and a lower per cent. of solids not fat as a result of the substitution of the by-products for the corn and bran. This difference is greatest on the richer foods, namely cream gluten meal and King gluten meal. Each of the three cows fed cream gluten meal and five of the seven fed King gluten meal narrowed the ratio of fat to solids not fat, while the two remaining did not change it. These figures show a general tendency of the gluten meals and feeds to produce a slightly richer milk. The gain, however, is too slight on the whole to lay much stress upon; yet it is added testimony to their worth when considered in connection with the decided gain in milk flow usually produced."

WHAT THESE EXPERIMENTS INDICATE.

The teaching of the experiments thus summarized is that liberal amounts of protein and narrow rations tend to increase the flow of milk and to lessen the natural shrinkage due to advanced period of lactation.

As to the influence of nitrogenous feeding stuffs on the composition of milk, the results of the majority of the experiments

here reported indicate that the narrow rations tended to increase the percentages of total solids and of fat in the milk to a slight degree. A rise of from .2 to .6 in the average percentages of fat in milk in favor of the narrow rations is seen in at least four of the experiments recorded. The individuality of the cow, however, seemed to be an important factor. While in the case of some cows a considerable change in the per cent. of solids and of fat was noticed, in other cases there seemed to be little or no change.

The percentages of fat in the total solids of the milk was larger in at least four of the experiments where the narrow rations were fed—that is, the proportion of fat to solids not fat seemed to be increased in these instances by the use of narrow rations.

With regard to the relative profit from the use of the narrow and the wide rations, there seems to be a diversity of opinion, but the general verdict of the experiments here recorded is in favor of the liberal use of nitrogenous feeding stuffs from the standpoint of profit, especially in the Eastern States. Whether under different conditions these feeds will prove profitable or not depends much upon their relative market values as compared with other feeding stuffs, such as corn and wheat feeds, which contain much less nitrogen. In the Eastern parts of this country nitrogenous feeding stuffs are relatively cheaper than in the West, and for this reason they can doubtless be used here to greater advantage. The soils of the East also are generally lacking in nitrogen, and the use of nitrogenous feeding stuffs tends to increase soil fertility by furnishing a manure rich in nitrogen.

Experiments by the Storrs Station.—These have been discussed in detail in the previous chapter. The especial object was the study of the feeding practice of Connecticut farmers. The experiments were made at a distance from the Station, and without the requisite facilities for complete analyses of the milk, and only the percentage of fat was determined. The results, therefore, throw comparatively little light on the effect of the feed upon the percentage of total solids in the milk, or the ratio of fats to total solids, but they emphasize very strongly the importance of protein for large yields of milk and

of butter-fat. In general the results accord with those obtained from the other American experiments above summarized.

It would be very interesting to summarize the results of European experimenting upon this subject, putting them in such form as to show in full detail their bearing upon the special questions here under consideration. Such a treatise, however, would exceed the bounds of the present report, and, furthermore, the European work has been discussed so frequently and in so much detail in other publications that the treatment here is hardly necessary.

UNDETERMINED FACTORS IN EXPERIMENTS OF THIS KIND.

In connection with experiments of this class, as they have been carried out both in this country and Europe, there is one question which has perhaps received too little consideration. It is this: In how far do experiments of short duration, continuing, as these have generally done, only from one to four weeks, or thereabouts, indicate what would be the effects of similar feeding if it were continued for a longer time, as, for instance, during the whole period of lactation? And further: What would be the effects of the same feeding if practiced continuously year after year? In other words, Is any special physiological influence exerted by a given ration, fed for a short time, which would not be maintained if the feeding were continued? Or, on the hand, Is there any possible effect of a given ration, which does not appear in a short test, but which might be gradually developed?

Of course to ask such questions as these is to imply a measure of doubt regarding the reliability of nearly all the experimental inquiries that have been carried out in this and similar lines. For this doubt there may be no valid reason, but it cannot be said that no such doubts exist.

These questions, furthermore, are such that a positive answer cannot be obtained without a large amount of laborious and time-consuming inquiry. Nevertheless, the subject is worthy of the thoughtful consideration of investigators.

Regarding the food also there are details which need to be examined more closely. One of these is the total quantity of the food. This is, perhaps, best measured by the potential energy or fuel value of the digestible nutrients. In the

experiments on the effects of wide *vs.* narrow rations or smaller *vs.* larger proportions of protein the total quantity of food eaten has not always been taken into account as it might have been. This criticism applies, indeed, to the discussion of the experiments by the Storrs Station in this and the preceding article. Thus, in the table on page 60, comparisons are made of the milk production of thirty-two dairy herds in Connecticut. The food of the cows in the sixteen herds with less than two pounds of digestible protein, per cow per day, furnished 26,900 calories of energy, while the food of the sixteen herds with more than two pounds of digestible protein per day had a fuel value of 29,600 calories. It is possible that the advantage in favor of the milk yield with the larger amount of protein may have been due in part to a larger amount of food. But, on the other hand, it will be observed, by reference to the same table, that when second tests were made with eleven of these herds, and the quantity of digestible protein was increased from an average of 1.78 to 2.40 pounds per day, the quantities of milk and milk fat were also increased, although the average potential energy of the food, per cow per day, was reduced from 28,100 calories in the former to 26,600 calories in the latter tests.

NEED OF ABSTRACT EXPERIMENTAL RESEARCH.

Any one who takes the pains to examine the reports of inquiry regarding the nutrition of animals and man, which have been carried out by experimental methods in Europe and in this country during the past twenty-five years and more, cannot fail to be impressed with the force of two important facts. One of these is, that the amount of experimenting has been very large and its cost very great.* The other is, that while the results already obtained are of incalculable value, one essential thing is still lacking, namely, the clear understanding of some of the fundamental laws of nutrition. Until these laws are more thoroughly understood it will be impossible to tell the farmer how he can feed his stock most economically. To learn them it will be necessary to develop a kind of experimenting which has thus far been too much neglected, especially in the

* See Bulletin 45 of the Office of Experiment Stations, U. S. Department of Agriculture, entitled "A Digest of Metabolism Experiments, by W. O. Atwater and C. F. Langworthy.

United States. This is the study of metabolism. It involves the weighing and measuring of not only food and milk, but also the excretory products, solid, liquid, and gaseous. To these should also be added the measurement of energy received and given off by the body. An effort in this direction is being made by the Storrs Station in the development of the respiration calorimeter, as stated elsewhere in this Report.

CONCLUSIONS—LARGE VS. SMALL PROPORTIONS OF PROTEIN AND NARROW VS. WIDE NUTRITIVE RATIOS IN FEEDING MILCH COWS.

As already stated we have here three special questions to consider regarding the effect of the food upon the milk production. The general question is: How do wide and narrow rations, or large and small quantities of protein, compare in their influence upon milk production? The special questions are:

1. What is the effect upon the total amount of milk produced?

2. What is the effect upon the percentage of solids in the milk? In like manner, What is the effect upon the total yield of milk solids, when both the total quantity and the composition of the milk are taken into account?

3. What is the effect upon the relative percentages of fat and other ingredients of the milk solids? And, in like manner, What is the effect upon the total yield of fat, protein, and other ingredients, when both the total amount and the composition of the milk are taken into account?

It is true that satisfactory answers to these questions are not found in the results of experimental inquiries thus far made. Such answers can only come from a large number of carefully planned, accurately performed, and long-continued tests with cows differing in breed and individual capacity for milk production, and fed upon a large variety of materials. Meanwhile, the following conclusions are, perhaps, justified:

1. A liberal amount of protein, considerably larger indeed, than is fed by a majority of Connecticut dairymen, is needed to produce the largest amount of milk and milk fat from a given amount of digestible nutrients in the food. In other words,

to meet the physiological demands of the cow for producing milk, liberal quantities of protein are essential.

2. With liberal feeding, and especially with food containing sufficient protein, both the total milk yield and the percentage of total solids in the milk may be brought to the maximum which the cow is capable of producing. With insufficient quantities of food, and especially with insufficient protein, both the total yield of milk and the percentage of total solids may be considerably less.

3. At times the ratio of butter-fat to other milk solids, in other words, the composition of the dry matter of the milk, appears to change with changes in the feeding. But the data obtainable from the experiments made up to the present time do not suffice to show exactly when or how these changes may be brought about.

STANDARD RATIONS AND FORMULAS FOR FEEDING DAIRY COWS.

There has been considerable discussion by agricultural writers in this country regarding the best standards or formulas for guidance in feeding farm animals, and there is no little misunderstanding as to the true meaning of a "standard" ration. To make the subject clear we must distinguish between three kinds of standards or formulas.*

One, which may be called the physiological standard, expresses the proportions of nutrients and energy which best fit the needs of the animal and the purpose for which it is fed. Such a physiological standard takes no account of the cost of the ration; it considers simply the needs of the animal for the work it has to perform.

The term "standard ration" is also commonly used to signify the ration which gives the best financial returns. This "standard" may take into consideration the physiological

* See discussion of this subject under title of "Standards for Rations and Dietaries," by W. O. Atwater, Report of this Station, 1894, pp. 205-221.

needs of the animal, but often does not. It considers mainly the relative cost of feeding stuffs and the amount and value of the product obtained from their use.

A third so-called "standard ration" is based upon the average practice of a large number of feeders; in other words, it expresses the average of a large number of rations found in actual use.

The confusion of terms might be avoided by making the term "standard ration" refer only to *the physiological standard*, while the second so-called standard might be designated as a *formula for profit*, and the third might be called an *average feeding ration* as found in practice. In the discussion of standard rations and formulas in the present article, this classification of terms will be followed.

Physiological standards.—We have here practically two physiological uses of food to consider, namely for maintenance and for production. The amounts and proportions of the different nutrients required to keep up the vital functions of the animal, that is to say, for maintenance, and those needed for production of milk, meat, work and the like, have been quite extensively studied by European experimenters. Using the results of such experiments and of more general studies of the laws of nutrition, several German authorities have proposed standard rations for milk production. The most commonly quoted of these is Wolff's, which calls for 2.5 pounds of digestible protein, .4 pounds of digestible fat, 12.5 pounds of digestible carbohydrates, per 1000 pounds live weight, and has a nutritive ratio of 1:5.4. While Prof. Wolff does not insist upon the distinction between physiological standards and formulas for feeding, his standard is recommended as representing, in a general way, the proportions which will be profitable for German feeders. He, however, urges the impracticability of establishing any fixed standard for profit that would apply to the feeding of animals under widely varying conditons.

Prof. Julius Kühn, another well-known German authority, has very cleverly pointed out the limitations in the use of feeding standards, although he insists upon their great value when properly used.* He insists upon the necessity of studying the

* See Experiment Station Record, Vol. IV., p. 6.

individual animal and fitting the food to its needs, rather than the adoption of any arbitrary standard. He calls attention to the fact that different breeds of milch cows and different cows of the same breed may vary widely with respect to the amounts of food which they can most advantageously utilize. The condition of the animal as to leanness or fatness may vary the amount and proportion of the different nutrients, and especially the amount of milk given at different times during the period of lactation will vary greatly the demands for food.

Prof. Kühn also calls attention to the fact that, in the feeding of milch cows, toward the end of the period of lactation it is important to consider whether they are to be fattened for the butcher or to calve and be milked again. If they are to be sold for beef when the milking stops they should have abundant food for fattening, but if they are to be kept for milk production they need not be as fat when they are dried before calving.

Prof. Maercker, also a well-known German authority, who has conducted numerous experiments on the feeding of cows for milk, insists very wisely that the modern high-bred cows with a very large capacity for milk production in proportion to their body weight, need much richer food than the ordinary cows of the present or the best cows of comparatively few years ago from which such production would be impossible.

The teachings of such men as these, which is based upon the latest and best experimenting and experience in Europe, where much more careful attention is given to such subjects than has been given until very lately in the United States, thus take into account very fully the needs of the animal for the special production demanded.

The feeding standards of Wolff have been published for many years, with his tables of composition of feeding stuffs and other most useful information, in a German Farmers' Calendar which has wide circulation among farmers and dairymen in that country. Since the death of Prof. Wolff the standards have been edited by Dr. Lehmann, who has made an attempt to fit them to the results of later experiments and experience.* In standards for milch cows Lehmann has given expression

*In the later volumes of Mentzel und von Lengerke's Landwirthschaftlicher Kalender.

to the fact that the ration needs to be fitted to the amount of milk given by the cows. He has calculated a series of rations for cows with different milk yields, and has increased the protein more than the fuel ingredients, thus making the rations narrower in proportion as the milk yield is larger. These rations are based upon the principle, now pretty clearly established, that a cow needs a liberal amount of protein to produce a large amount of milk.

Formulas for profit.—The practical farmer feeds for profit, and the ration which will produce the largest amount of growth or the largest amount of milk and butter-fat, or will enable the animal to perform the greatest amount of work, may not be the most profitable. In other words, the physiological standard may not be the most profitable ration for feeding. The physiological action of the nutrients is the chief factor in their profitable use, but other conditions, such as the cost of the feed and the value of the products, must be taken into account. It may be more profitable to use a wide ration when a narrower ration would give a larger amount of product. To find the most profitable formula for feeding, inquiry in two lines is especially needed. These are: (1) Accurate observations of the actual feeding practice of farmers and of the resulting product; and (2) more accurate experimenting by the stations for the purpose of comparing the relative values of widely varying rations when the cost of the feeding stuffs and the value of the resulting products are taken into account.

In the somewhat extended study of the feeding practice of Connecticut dairymen, reported in the previous article, it was pointed out that the largest yields and the best financial results were generally obtained where liberal quantities of protein were fed. Where the results with eleven wide rations were compared with those obtained from eleven narrower ones fed to the same herds, the average cost of producing 100 pounds of milk was $1.03 when the wide rations were fed, and 97 cents when the narrower rations were fed, while the cost of producing one pound of butter in the two cases was 19 cents for the wide and 17 cents for the narrower rations.

In the above compilation (pp. 102, 103) of experiments on the effect of wide and narrow rations, as studied at different

experiment stations, the results when viewed from a financial standpoint are nearly always in favor of narrow rations, or in other words, of the use of large quantities and proportions of protein. Of course, account must be taken of the fact that the relative value of feeding stuffs high in protein and high in carbohydrates varies at different times, and especially in different parts of the country. For example, feeds containing large proportions of carbohydrates are relatively cheaper in the West than in New England. The ration that would be most economical in Connecticut might be far from economical in Wisconsin.

Average Feeding Rations as found in practice.—Attempts have been made from time to time to construct so-called "standards" for rations upon the basis of the actual practice of intelligent feeders. A formula of this kind, which has been designated as "An American Standard Ration for Dairy Cows," has been published by the Wisconsin Agricultural Experiment Station, and widely circulated.* The data for amounts of feeding stuffs used and of milk produced were taken from replies made by dairymen to letters of inquiry. The figures given represented the estimates made by the persons reporting. The feeding stuffs were neither weighed nor analyzed. The composition and digestibility were estimated from average analyses. The reports from a large number of dairymen in the United States and Canada gave 128 rations, which were estimated to supply per day from 1 to 4 pounds of digestible protein, from .1 to 1.3 pounds of digestible fat, and from 8 to 19 pounds of digestible carbohydrates, the nutritive ratio varying from 1:4 to 1:13. The average of these was taken for the standard.†

Another "standard" has recently been published.‡ This is based upon the actual practice of an expert in the feeding of a small herd of cows at the Experiment Station in Michigan through the greater part of two winters. The quantities of the different feeding stuffs making up the daily rations were regulated by the judgment of the feeder. The feeds were

* Bulletin 38, Wisconsin Agricultural Experiment Station.

† Reference was made to this standard in the Reports of this Station for 1895, pp. 62, 63, and 1896, pp. 71, 72.

‡ Bulletin 149, Michigan Agricultural Experiment Station.

analyzed and the digestibility was calculated from average digestion coefficients. The rations as actually fed varied considerably. This variation is noticeable with the same cow at corresponding periods of lactation in the two separate winters. No comparison was made of the results obtained with the different and distinct rations. The author of the Bulletin points out some of the limitations of feeding standards in the following language:

"A study of the tables of rations and yields of milk and butter-fat shows conclusively that an expert feeder varies the size of the ration, not according to the weight of the cow alone, or primarily, but according to her capacity to receive, and her ability to yield, and that, with the same cow, the ration is modified as the period of lactation advances, to conform to the requirements of the system.

"What is true of the dry matter is true of the digestible protein. Where a cow is secreting a large amount of milk * * * her food must be relatively richer in protein than when she has not this demand upon her system to supply. The food requirements of the system to sustain the vital functions remain comparatively constant. To these requirements is superadded, in the periods of greatest milk yields, the demand for the butter and cheese in the milk. Protein is required not only to supply the casein of the milk, but to insure that active vitality which is involved in butter production."

The discussion is aptly summarized by saying that skilled feeding must take into consideration the productiveness of the cows, their variations in live weight, the effects of the various feeding stuffs upon the quality of the butter and upon health of the cow, the money values of the feeding stuffs, and, finally, the net profit obtained from their use.

In previous reports of this Station a formula for daily rations for milch cows has been given.* This, like other proposed formulas, was simply a suggestion based upon experiment and observation. It was similar to Wolff's German standard, but provided a larger proportion of digestible carbohydrates and had, consequently, a larger total amount of nutrients than Wolff's. Stress was laid upon the fact that it was tentative and subject to such alteration as further experience might call for. In the discussion of the subject the principle was repeatedly urged that either a physiological standard or a formula for profit to feed all cases is not only irrational, but impossible.

The use of the word standard as applied to formulas for feeding may be of questionable advisability. A standard, when used in the sense of the best practice, may be defined as "that

* See Report of Storrs Station for 1896, p. 71.

which is established as a rule or model for guidance based upon experience.'' A so-called standard ration based upon the average feeding practice of dairymen or upon the practice of different dairymen with different herds in different places or upon the practice of a single feeder with a single herd could hardly be taken as a model for guidance. The best formula for profit even assuming that it might be called a ''standard ration'' cannot be obtained from the practice of feeders working under widely varying conditions. The futility of such an attempt is illustrated by the experience set forth in the previous article on ''A Study of Rations fed to Milch Cows in Connecticut.'' A number of average rations were there given together with the amounts of milk and butter-fat obtained when they were used. One of these was the average of thirty-two rations as found in actual use. In order to compare the results obtained with larger and with smaller quantities of protein the herds and rations were divided into two groups,* those with more than two pounds of digestible protein and those with two pounds or less of digestible protein per cow per day. The group including the cows with more than two pounds of digestible protein per day consisted of 43 registered, 161 grade and 23 native cows, making 227 in all. The group including the cows receiving less than two pounds of digestible protein per day included 30 registered, 164 grade and 32 native cows, making 226 animals. Nearly all of the registered and grade animals in both groups were Jerseys and Guernseys. It is thus seen that there was no very great difference between the two groups of sixteen herds each as regards the breeds of cows. The Station representative who visited the herds, weighed the fodder and took samples for analysis, and weighed and analyzed the milk, found nothing to indicate any especial difference in either the selection or the management of the two different groups. In other words, aside from the feed there was no apparent reason for expecting any difference in the milk and butter yields.

The average daily yield of butter obtained where more than two pounds of digestible protein were fed would have been worth 3.6 cents more than the average obtained from the other group, if the butter is estimated at 20 cents per pound.

* See table on page 60.

The actual cost of the rations in the two groups is not known, but in eleven other instances when close comparisons were made between the use of rations containing larger quantities and proportions of protein and those containing smaller quantities and proportions,* the results in general were in favor of the larger quantities of protein. It is evident that in the case of these two groups of rations the average of those containing over two pounds of digestible protein would be nearer a model than the average of those with the smaller amounts of protein or than the average of all, yet we should hardly feel warranted in setting up any one of these as a "standard" or formula to be recommended for general use.

FITTING FEEDING FORMULAS TO MILK FLOW.

In what has just been said we do not by any means wish to imply that formulas for feeding are not valuable. On the other hand we maintain, as this Station has constantly done, that such formulas are highly useful as general indications for the practical feeder to follow. Furthermore, we believe that it is wise to make continual use of the results of experience and experiment in the changing and improving of such formulas.

It has been quite customary to base standards and formulas for the feeding of milch cows mainly upon the live weight of the animal and an average condition of productiveness. In the last Annual Report of this Station† experiments were cited and a tentative ration, previously suggested, was repeated. The following statement was also made:

> "The experience of the Station for the last two years would, however, indicate that in general it is more profitable to feed a cow 'in the flush' rather more protein than the suggested ration calls for. The very decided trend of these experiments is toward nitrogenous feeding for milk production."

It seems to the writers that the time has come for applying this principle. This has indeed been done by proposing rations which furnish more protein and have narrower nutritive ratios in proportion as the cows give larger milk yields, and which reduce the amount of protein as the milk yield decreases.

Such rations are based upon the fact that the most important use of protein in feeding dairy cows is in the formation of milk. In the Report of the Station for 1896 a number of so-called

* See table 10, p. 63.

† Report for 1896, p. 84.

standard rations were given. Among these were Lehmann's formulas for cows with different milk yields. In these rations the quantity of protein recommended to be fed was largely increased in accordance with the increase of milk product of different cows. The studies made by this Station, as well as those which have been compiled from the work of other Stations, tend to point out the wisdom of this system of feeding. In the table which follows will be found Lehmann's German formulas for cows with different milk yields, and several formulas suggested by the writers. The plan of these feeding formulas is similar to Lehmann's in that the protein is increased according as the milk yield is larger, although the increase in protein is less rapid in our proposed formulas. Allowance is thus made for the relative cheapness in this country of feeding stuffs rich in the carbohydrates. These formulas provide for a *basal* ration which shall be fed to all cows of the herd giving ten or more pounds of milk per day. This is supposed to include all of the cows giving milk, except those which may be "drying off" preparatory to calving. An increase of three-tenths of a pound of protein for every five pounds increase (above twenty pounds) in the milk flow per day is provided for the heavier milk producers. The carbohydrates and fat are at the same time increased somewhat, but not relatively as fast as the protein, so that the nutritive ratios of the rations become narrower as the milk product increases in amount. One possible weakness in this system of feeding is found in the fact that the quality of the milk is left out of consideration. It would doubtless be more rational to feed animals in accordance with the total amount of solids produced in the milk than in accordance with the milk flow, but as there is no simple and rapid means of determining the percentage of solids in the milk this plan is hardly feasible. The use of rations which shall vary in accordance with the milk product is comparatively simple, as it only requires that the weight of milk given from day to day shall be known.

RATIONS FOR DAIRY COWS.

It is practically impossible to formulate feeding rations that will be applicable for use under the great variety of conditions found upon different dairy farms. The kinds and quality of

the coarse fodders available for use must be taken into consideration before concentrated feeds can be purchased and used with the best results. The feeder, then, must be guided in part by the coarse fodders available for use. The rations, to be profitable, must also vary with the kind and condition of the stock to be fed, and the price received for their products. The feeder must be guided largely by the market value of feeds, their manurial values, the returns that he receives for his products, and the feeding capacities and productiveness of the different animals of the herd. The price of feeds at one time may be such as to make a wide ration more profitable than a narrow one. As a rule, however, when the direct animal products and the manure are both taken into account, the liberal feeding of narrow rations, with large quantities of protein, is found to be the most profitable in Connecticut.

Proposed standard rations for milch cows, by Lehmann, and suggested feeding formulas, by the Station.

Milk per Cow per Day.	Dry Matter.	Digestible Nutrients. Protein.	Fat.	Carbo-hydrates.	Fuel Value.	Nutritive Ratio.
	Lbs.	Lbs.	Lbs.	Lbs.	Cal.	1:
Lehmann's (German) Standards. Cows of 1000 Lbs. Live Weight.						
5 kilos or 11 pounds, - - - -	25	1.6	.3	10	22850	6.7
7½ kilos or 16½ pounds, - -	27	2.0	.4	11	25850	6.0
10 kilos or 22 pounds, - - -	29	2.5	.5	13	30950	5.7
12½ kilos or 27½ pounds, - -	32	3.3	.8	13	33700	4.5
Suggested Feeding Formulas. Cows of 700–950 Lbs. Live Weight.						Average.
10 to 20 pounds (basal ration), - -	20–22	2.0	.3–.5	10–12	25900	6.0
20 to 25 pounds, - - - - -	21–23	2.3	.4 .6	10–12	26900	5.3
25 to 30 pounds, - - - - -	21–23	2.6	.4–.6	10–12	27400	4.7
30 to 35 pounds, - - - - -	22–24	2.9	.5–.7	11–13	30200	4.6
35 to 40 pounds, - - - - -	22–24	3.2	.5–.7	11–13	30800	4.2
Cows of 950–1100 Lbs. Live Weight.						
10 to 20 pounds (basal ration), - -	22–24	2.3	.4–.6	12–14	30600	6.1
20 to 25 pounds, - - - - -	23–25	2.6	.5–.7	12–14	31600	5.5
25 to 30 pounds, - - - - -	23–25	2.9	.5–.7	12–14	32100	5.0
30 to 35 pounds, - - - - -	24–26	3.2	.6–.8	13–15	34900	4.9
35 to 40 pounds, - - - - -	24–26	3.5	.6–.8	13–15	35500	4.4

Animals differ widely in their feeding capacities, and the successful feeder must be a close observer, and must vary his feeds in accordance with the appetites of his animals. The most vigorous eaters are generally the most profitable animals

As a general rule, the greater the amount of food eaten the greater will be the proportion available for the formation of marketable products. Profitable feeding requires that the feed be regulated by the quantity and quality of these products. The uses of the food are to repair the worn out tissues of the animal machine, to supply heat and energy, and to build up new products. The wastes of the animal machine and the fuel required for heat and for muscular work—in other words, the demand for maintenance, do not seem to vary much for differences of one to two hundred pounds in live weight, but differences of five to ten quarts per day in the milk product will involve very different demands for food.

The following rations for milch cows have been formulated with the plan in view of utilizing home grown nitrogenous feeding stuffs, and of supplementing these mainly by the addition of concentrated nitrogenous feeds, the latter to be increased in accordance with the milk production. A "basal ration" is recommended for cows giving from ten to twenty pounds of milk per day. This is to be fed to all animals of the herd with the exception of those which are well advanced in the period of lactation, and which are naturally shrinking rapidly in milk flow. The basal ration is essentially the same as the tentative standard heretofore recommended by this Station for cows of about 800 pounds live weight. To this basal ration is added, for all cows giving over twenty pounds of milk per day, a "protein mixture" made up of highly nitrogenous grain feeds. The proportions of the materials are such that one pound of this mixture furnishes about three-tenths of a pound of digestible protein. One pound of the mixture is to be added for each five pounds increase in the milk flow above twenty pounds per day. These rations are based on the formulas given on page 121, for cows weighing from 750 to 950 pounds live weight. Rations for heavier cows can be calculated in the same way by using as a basis the formulas found in the lower part of the table. These formulas call for larger rations than those for lighter cows, but the nutritive ratio is practically the same. Cows weighing 1000 pounds or more would probably require an increase in all of the nutrients. These rations have been calculated from table 11, pages 80, 81, giving the proportion of digestible nutrients in the different feeding stuffs.

Ration A is designed for use where the more marketable grades of hay are to be sold. It brings into use the cheaper coarse fodders to replace the hays. It also provides for the use of corn meal, which, with the stover, utilizes the entire corn crop when this is not placed in the silo. One possible defect is the absence of any succulent food. This might be provided by adding some kind of roots, as beets or carrots.

Ration A.

Ration A.	Amount.	Total Dry Matter.	Digestible Nutrients and Fuel Value.				Nutritive Ratio.
			Protein.	Fat.	Carbo-hydrates.	Fuel Value.	
Ration for Cows giving 10–20 Lbs. of Milk Per Day.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Cal.	1:
Basal ration:							
Corn stover, - - -	5	4.3	.13	.06	2.3	4750	—
Clover hay, - - -	10	9.2	.69	.10	3.8	8770	—
Wheat bran, - - -	4	3.5	.48	.11	1.5	4220	—
Chicago gluten meal, -	2	1.8	.63	.11	.8	3275	—
Corn meal, - - -	2	1.7	.12	.08	1.3	3010	—
Total ration, - -	—	20.5	2.05	.46	9.7	24025	5.2
Ration for Cows giving 20–25 Lbs. of Milk.							
Basal ration (as above), -	—	20.5	2.05	.46	9.7	24025	5.2
Protein mixture:							
Cotton seed meal, 1 part, Chic. gluten meal, 2 parts,	1	.9	.33	.08	.3	1600	—
Total ration, - -	—	21.4	2.38	.54	10.0	25625	4.7
Ration for Cows giving 25–30 Lbs. of Milk.							
Basal ration (as above), -	—	20.5	2.05	.46	9.7	24025	—
Protein mixture, - - -	2	1.8	.66	.16	.6	3200	—
Total ration, - -	—	22.3	2.71	.62	10.3	27225	4.3
Ration for Cows giving 30–35 Lbs. of Milk.							
Basal ration (as above), -	—	20.5	2.05	.46	9.7	24025	—
Protein mixture, - - -	3	2.7	.99	.24	.9	4800	—
Total ration, - -	—	23.2	3.04	.70	10.6	28825	4.0

Ration B is suited for use on farms where the corn crop is preserved as silage, and where cheaper coarse hays and some rowen are available. A small amount of coarse, bulky hay, such as would be furnished from the poorer grasses, or from oats, is very valuable for use with the silage. The use of rowen lessens the amount of gluten feed that would be needed to give a well-balanced ration. The Cleveland flax meal is an improved new process linseed; samples recently sold in the markets contain as high as 35 to 40 per cent. of protein. Such a feed, therefore, is valuable for increasing the nitrogenous part of the ration.

Ration B.

Ration B.	Amount.	Total Dry Matter.	Digestible Nutrients and Fuel Value. Protein.	Fat.	Carbohydrates.	Fuel Value.	Nutritive Ratio.
Ration for Cows giving 10–20 Lbs. of Milk Per Day.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Cal.	1:
Basal ration:							
Corn silage, - - -	30	7.4	.30	.21	4.2	9300	—
Oat hay, - - -	3	2.7	.14	.06	1.0	2445	—
Rowen hay (mixed grasses),	5	4.2	.47	.08	2.0	4925	—
Wheat bran, - - -	4	3.5	.48	.11	1.5	4220	—
Buffalo gluten feed, -	3	2.7	.68	.10	1.5	4410	—
Total ration, - -	—	20.5	2.07	.56	10.2	25300	5.5
Ration for Cows giving 20–25 Lbs. of Milk.							
Basal ration (as above), -	—	20.5	2.07	.56	10.2	25300	5.5
Protein mixture:							
Clevel'd flax meal, 2 parts, Buffalo gluten feed, 1 part,	1	.9	.30	.03	.4	1410	—
Total ration, - -	—	21.4	2.37	.59	10.6	26710	5.0
Ration for Cows giving 25–30 Lbs. of Milk.							
Basal ration (as above), -	—	20.5	2.07	.56	10.2	25300	—
Protein mixture, - - -	2	1.8	.60	.06	.8	2820	—
Total ration, - -	—	22.3	2.67	.62	11.0	28120	4.6
Ration for Cows giving 30–35 Lbs. of Milk.							
Basal ration (as above), -	—	20.5	2.07	.56	10.2	25300	—
Protein mixture, - - -	3	2.7	.90	.09	1.2	4230	—
Total ration, - -	—	23.2	2.97	.65	11.4	29530	4.3

Ration C is designed especially to utilize the corn crop where this is grown and field cured. The clover rowen adds considerably to the proportion of protein in the ration, so that much less of the Chicago gluten is needed to make it well-balanced. The liberal proportion of clover rowen in the ration would probably make the use of succulent feeds unnecessary, although a small proportion of roots would, perhaps, be helpful.

Ration C.

Ration C.	Amount.	Total Dry Matter.	Digestible Nutrients and Fuel Value. Protein.	Fat.	Carbo-hydrates.	Fuel Value.	Nutritive Ratio.
Ration for Cows giving 10–20 Lbs. of Milk Per Day.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Cal.	Lbs.
Basal ration:							
Clover rowen hay, - -	8	7.1	.81	.17	2.9	7560	—
Corn stover, - - -	8	6.9	.20	.09	3.7	7600	—
Wheat middlings, - -	4	3.5	.48	.14	2.0	5240	—
Chicago gluten meal, -	1	.9	.32	.06	.4	1640	—
Corn meal, - - -	3	2.6	.17	.12	2.0	4515	—
Total ration, - -	—	21.0	1.98	.58	11.0	26555	6.1
Ration for Cows giving 20–25 Lbs. of Milk.							
Basal ration (as above), -	—	21.0	1.98	.58	11.0	26555	6.1
Protein mixture:							
Chic. gluten meal, 2 parts, O. P. linseed meal, 1 part,	1	.9	.31	.06	.4	1570	—
Total ration, - -	—	21.9	2.29	.64	11.4	28125	5.6
Ration for Cows giving 25–30 Lbs. of Milk.							
Basal ration (as above), -	—	21.0	1.98	.58	11.0	26555	—
Protein mixture, - - -	2	1.8	.62	.12	.8	3140	—
Total ration, - -	—	22.8	2.60	.70	11.8	29695	5.1
Ration for Cows giving 30–35 Lbs. of Milk.							
Basal ration (as above), -	—	21.0	1.98	.58	11.0	26555	—
Protein mixture, - - -	3	2.7	.93	.18	1.2	4710	—
Total ration, - -	—	23.7	2.91	.76	12.2	31265	4.7

Ration D is a much wider ration than is commonly recommended, owing to the large proportion of corn silage and coarse hays that are found in it. Where an abundance of cheap grades of hay and corn silage are available, such a ration might be more profitable than a narrower one, which would contain a larger proportion of protein. The mixture of cotton seed meal and Buffalo gluten feed rapidly increases the protein in the rations designed for the heavier milk producers.

Ration D.

Ration D.	Amount.	Total Dry Matter.	Digestible Nutrients and Fuel Value. Protein.	Fat.	Carbo-hydrates.	Fuel Value.	Nutritive Ratio.
Ration for Cows giving 10–20 Lbs. of Milk Per Day.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Cal.	1:
Basal ration:							
Corn silage, - - -	30	7.4	.30	.21	4.2	9300	—
Hay (mixed grasses), -	4	3.4	.19	.05	1.7	3660	—
Oat and pea hay, - -	6	5.0	.35	.04	2.3	4980	—
Wheat bran, - - -	4	3.5	.48	.11	1.5	4220	—
Buffalo gluten feed, -	3	2.7	.68	.10	1.5	4410	—
Total ration, - -	—	22.0	2.00	.51	11.2	26570	6.2
Ration for Cows giving 20–25 Lbs. of Milk.							
Basal ration (as above), -	—	22.0	2.00	.51	11.2	26570	6.2
Protein mixture:							
Buff. gluten feed, 2 parts, Cotton seed meal, 3 parts,	1	.9	.31	.09	.3	1500	—
Total ration, - -	—	22.9	2.31	.60	11.5	28070	5.6
Ration for Cows giving 25–30 Lbs. of Milk.							
Basal ration (as above), -	—	22.0	2.00	.51	11.2	26570	—
Protein mixture, - - -	2	1.8	.62	.18	.6	3000	—
Total ration, - -	—	23.8	2.62	.69	11.8	29570	5.0
Ration for Cows giving 30–35 Lbs. of Milk.							
Basal ration (as above), -	—	22.0	2.00	.51	11.2	26570	—
Protein mixture, - - -	3	2.7	.93	.27	.9	4500	—
Total ration, - -	—	24.7	2.93	.78	12.1	31070	4.7

Ration E is designed especially to utilize the corn crop where this is cured in the field. The corn crop is also supplemented quite largely by oat hay and rowen. A variety of the feeds rich in protein is used, and this variety, together with a liberal proportion of corn meal and wheat bran, would tend to make the ration a valuable one for butter production.

Ration E.

RATION E.	Amount.	Total Dry Matter.	Digestible Nutrients and Fuel Value. Protein.	Fat.	Carbo-hydrates.	Fuel Value.	Nutritive Ratio.
Ration for Cows giving 10–20 Lbs. of Milk Per Day.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Cal.	1:
Basal ration:							
Oat hay, - - -	4	3.5	.18	.08	1.4	3260	—
Corn stover, - - -	6	5.1	.15	.07	2.8	5700	—
Rowen hay (mixed grasses),	6	5.1	.56	.10	2.4	5910	—
Wheat bran, - - -	3	2.6	.36	.08	1.2	3165	—
N. P. linseed meal, -	2	1.8	.57	.05	.7	2610	—
Corn meal, - - -	3	2.6	.17	.12	2.0	4515	—
Total ration, - -	—	20.7	1.99	.50	10.5	25160	5.8
Ration for Cows giving 20–25 Lbs. of Milk.							
Basal ration (as above), -	—	20.7	1.99	.50	10.5	25160	5.8
Protein mixture:							
Cotton seed meal, 1 part, Chic. gluten meal, 2 parts,	1	.9	.33	.08	.3	1600	—
Total ration, - -	—	21.6	2.32	.58	10.8	26760	5.2
Ration for Cows giving 25–30 Lbs. of Milk.							
Basal ration (as above), -	—	20.7	1.99	.50	10.5	25160	—
Protein mixture, - - -	2	1.8	.66	.16	.6	3200	—
Total ration, - -	—	22.5	2.65	.66	11.1	28360	4.8
Ration for Cows giving 30–35 Lbs. of Milk.							
Basal ration (as above), -	—	20.7	1.99	.50	10.5	25160	—
Protein mixture, - - -	3	2.7	.99	.24	.9	4800	—
Total ration, - -	—	23.4	2.98	.74	11.4	29960	4.4

Ration F is given more particularly to show the increased value of a mixed silage of corn and soy beans as compared with corn alone. The 25 pounds of this mixed silage gives four-tenths of a pound of protein, while in ration D 30 pounds of corn silage only furnishes three-tenths of a pound. The clover rowen in this ration also helps to increase the protein, so that but one pound of Buffalo gluten is needed to give a well-balanced ration.

Ration F.

Ration F.	Amount.	Total Dry Matter.	Digestible Nutrients and Fuel Value. Protein.	Fat.	Carbo-hydrates.	Fuel Value.	Nutritive Ratio.
Ration for Cows giving 10–20 Lbs. of Milk Per Day.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Cal.	1:
Basal ration:							
Corn and soy bean silage,	25	6.0	.40	.18	3.3	7605	—
Clover rowen, - -	5	4.4	.51	.11	1.8	4725	—
Oat hay, - - -	3	2.7	.14	.06	1.0	2445	—
Wheat bran, - - -	5	4.4	.60	.14	1.9	5275	—
Corn meal, - - -	2	1.7	.12	.08	1.3	3010	—
Buffalo gluten feed, -	1	.9	.23	.03	.5	1470	—
Total ration, - -	—	20.1	2.00	.60	9.8	24530	5.6
Ration for Cows giving 20–25 Lbs. of Milk.							
Basal ration (as above), -	—	20.1	2.00	.60	9.8	24530	5.6
Protein mixture:							
Buff. gluten feed, 2 parts, Cotton seed meal, 3 parts,	1	.9	.31	.09	.3	1500	—
Total ration, - -	—	21.0	2.31	.69	10.1	26030	5.0
Ration for Cows giving 25–30 Lbs. of Milk.							
Basal ration (as above), -	—	20.1	2.00	.60	9.8	24530	—
Protein mixture, - - -	2	1.8	.62	.18	.6	3000	—
Total ration, - -	—	21.9	2.62	.78	10.4	27530	4.6
Ration for Cows giving 30–35 Lbs. of Milk.							
Basal ration (as above), -	—	20.1	2.00	.60	9.8	24530	—
Protein mixture, - - -	3	2.7	.92	.27	.9	4500	—
Total ration, - -	—	22.8	2.92	.87	10.7	29030	4.3

IN CONCLUSION.

In the above discussion the following principles are urged:

1. Profitable feeding re[illegible]the food be fitted to (a) the individual peculiarities of the animals and their especial demands for production, and (b) the cost of the food and value of the products. The successful feeder will regulate his feeding by his animals and the markets. To be successful he must understand both.

2. A standard ration, to fit all cases, is out of the question. Thus physiological standards must differ with differences in the animals fed and in the production required of them. Different breeds of steers or swine will respond differently to the food given them for fattening. Different breeds of cows and different cows of the same breed will differ even more widely in their demands of food for maintenance or for milk production. Formulas for profit must differ likewise, not only with the animals and the production required, but with prices of food and of products in different localities and seasons. There is no such thing as a "best ration" for milch cows or for animals of any other class.

3. At the same time formulas for feeding are very useful as general indications to be used in connection with the feeder's observation of his animals and the markets.

4. In feeding milch cows it makes a great difference whether the animals are yielding a large or a small amount of milk. A large milk yield requires a large supply of material to make casein, fat, and other compounds of the milk. From the physiological standpoint one chief essential is abundant protein.

5. As a rule, liberal feeding of rations rich in protein has been found the most profitable where observations have been made by the Station in Connecticut. This is especially true when the value of the manure is taken into account.

6. The rations here given represent attempts to indicate mixtures of feeding stuffs of such kinds, amounts, and costs as experience of the Station implies to be advantageous for Connecticut dairymen. Like the rations previously suggested by the Station they are tentative suggestions and, of course, open to revision and improvement.

STUDIES OF DIETARIES.

REPORTED BY W. O. ATWATER AND A. P. BRYANT.

One of the lines of inquiry with which the Station has been, and is still occupied, has to do with the food consumption of individuals, families, and boarding clubs. The purpose is to accumulate definite information regarding the practice of people of different classes, and in different places, in respect to the purchase and use of their food. Such information, coupled with that which comes from the study of the composition, digestibility, and nutritive value of our common food materials and from research into the laws of nutrition, including such as is illustrated by the metabolism experiments in which the Station is engaged, will gradually make it possible to judge as to what are the more common dietary errors and how improvements may be made to the advantage of health, purse, and home life. To this end, however, much painstaking research will be necessary. It is very fortunate that a considerable number of experiment stations, colleges, and other organizations, as well as private individuals, in different parts of the country, are coöperating in such inquiries under the leadership of the U. S. Department of Agriculture, so that the much needed knowledge is accumulating much more rapidly than would otherwise be possible.

The methods followed in conducting dietary studies have been fully described in previous Reports of the Station.* The general plan includes (1) determinations of the amounts and costs of different food materials on hand at the beginning of the study, purchased during and remaining at the close of the investigation; (2) when practicable, the collection and analysis of all kitchen and table waste; (3) a record of the occupation, age and sex of the different members of the family or club and the number of meals taken by each person. From the above data and those for the composition of the food materials as

* See Reports of this Station for 1891–1896.

found by analysis, either of specimens of the food materials actually used or of similar materials, can be computed the total amounts of protein, fats and carbohydrates consumed, and the amounts per man per day.

Accounts of dietary studies by the Station have been given in previous reports as follows:

Dietaries of farmers' families.—These comprise nine studies; Nos. 27, 45, 46, 120, 121 and 123 published in the Report of the Station for 1895; and Nos. 156, 157 and 174 in the Report for 1896.

Dietaries of mechanics' families.—These comprise nine studies; No. 1, in the Report for 1891; Nos. 4, 5, 6, 7 and 8 in the Report for 1892; Nos. 10 and 11 in the Report for 1893; and No. 21 in the Report for 1894.

Dietaries of professional men's families.—These comprise nine studies; No. 2 in the Report for 1891; Nos. 3, 9 and 13 in the Report for 1893; No. 4 in the Report for 1894; and Nos. 26, 28, 29 and 169 in the Report for 1895.

Dietaries of students' clubs.—These comprise five studies; No. 12 published in the Report of the Station for 1893; Nos. 16, 17 and 18 in the Report for 1894; and No. 124 in the Report for 1895.

Miscellaneous.—These comprise eight studies; Nos. 14 (a widow's family), 15 and 19 (a Swedish laborer's family) in the Report for 1894; and Nos. 23 and 24 (poor families in Hartford), 173 (a private boarding house), 175 (a man in the Adirondacks) and 176 (a camping party in Maine) in the Report for 1896.

STUDIES IN 1897.

In the present Report six additional studies are given:

No. 184, a man in the Adirondacks under treatment for consumption (same person as No. 175).

No. 202, same subject as in Nos. 175 and 184.

No. 203, a farmer's family in New York.

Nos. 223 and 224, a family in the Adirondacks, No. 223 was of the same subject as Nos. 175, 184 and 202; No. 224 was a study of two ladies, relatives of the preceding.

No. 226, a private boarding house.

EXPLANATION OF TABLES.

The following statements and tables contain the main results of the inquiries, including all the data used in the computations. The statistics in each dietary include the kinds of food materials used, with the weight and cost of each, the number of meals taken by each person, and the computed cost, nutrients and fuel value of the food per man per day.

Composition of food materials.—The figures used for the percentage of nutrients in each food material are taken from an unpublished revision of Bulletin No. 28 of the Office of Experiment Stations of the U. S. Department of Agriculture, on the Composition of American Food Materials. The values are but little changed from those given in the Report of the Station for 1896.*

Details of individual dietaries.—The introductory statements for each dietary study give the statistics upon which are based the number of meals for one man computed as equivalent to those actually eaten by the whole family or club. The first table for each study shows the amounts and costs of the different food materials used during the period of the study. For economy of space the details of total amounts of protein, fat and carbohydrates in each food material given in previous reports are omitted here. The second table in each case gives the quantities of nutrients per man per day furnished by different groups of food materials. It shows also the percentages which the different kinds of food, and the nutrients contained therein, make of the total food and total nutrients. The final table in each case summarizes the results per man per day, and shows also the fuel value of the nutrients, and the amounts of nutrients and energy wasted.

Waste.—The words "refuse" and "waste" are used somewhat indiscriminately. In general, "refuse" in animal food represents inedible material, although bone, tendon, etc., which are classed as refuse, may be utilized for soup. The refuse of vegetable foods, such as parings, seeds, etc., represent not only inedible material, but also more or less of edible material. The waste includes the edible portion of the food, as pieces of meat,

* The Average Composition of American Food Materials, Report of Storrs Experiment Station, 1896, pp. 190-198.

bread, etc., which might be saved, but is actually thrown away with the refuse.

In the studies here described the refuse and waste were separated as completely as practicable, and the latter collected and either dried and analyzed, or the nutrients calculated from the weights and percentage composition of the different food materials making up the waste.

DIETARY STUDIES OF AN INVALID.

In the Report of the Station for 1896 a dietary study was published of a gentleman who was suffering from pulmonary tuberculosis, and was living in the Adirondack region of New York, where persons affected by this disease resort for alleviation or cure. In the present Report three more studies of the diet of the same person are given. These, like the previous ones, were made by the young man himself, who had become much interested in such inquiries. His education and training had been such as to give value to the results of his work, and the reports show evidence of no little painstaking in the carrying out of the details. The weighings of food and waste were made in part with "reliable steelyards" and in part with grocer's scales. The observations are of interest as an illustration of the dietary habits of an intelligent person affected by this disease and acting under the advice of physicians in the hope of relief or cure. They represent the food consumption of a man with light exercise and under more or less abnormal conditions.

Conditions under which the subject lived.—The subject was obliged to follow certain courses of treatment and could not endure prolonged or severe exercise. At the time of the first study he had been residing in the Adirondacks for six years, the most of which time was spent at hotels and boarding houses. He had, however, become weary of hotel life and had rented a cottage and was boarding himself. This gave him abundant opportunity to carry on such investigations as those here reported. Influenced partly by the advice of his physicians and partly by a tendency said to be not uncommon with those affected by such disease he consumed large quantities of meat in proportion to vegetable foods. The results of this are shown in the unusually large amount of protein consumed—in the first studies amounting, in one case, to 200 grams per day.

As stated above the amount of exercise was not large. It consisted mainly of the labor required in light housekeeping and in short walks. Even in the coldest weather much of the time was spent sitting in the open air, well protected by wraps.

The studies here reported were made in the winter (No. 184), spring (No. 202), and summer (No. 223) of 1897. The winter study comprised six weeks in February and March. The minimum temperature during the month of February was —28° F., the maximum +50° and the approximate mean 18°. During this period from 5 to 5½ hours per day were spent out of doors, and at night the windows of the sleeping room were left open. The subject estimates from numerous observations of the thermometer that the temperature of the air in the sleeping room was, on the average, not far from 15° F., and that the mean temperature of the air in which he lived during the period was not far from 35°. During the period of 14 days in May, when the spring dietary study was made, the minimum temperature recorded was 29°, the maximum 78° and the mean not far from 53° F. (obtained by averaging the maxima and minima for the different days). The average temperature of the air in which he lived he estimates to have been about 56° in the day time and 47° at night. The summer study was made in August, it continued 14 days, during which period the minimum temperature was 38°, the maximum 83°, and the mean about 62° F. Many of the temperature records were furnished by the weather observer at Saranac Lake not far distant.

Results.—The study of the previous winter (January and February, 1896) had shown a daily consumption of food sufficient to yield 200 grams of protein and a fuel value of 4,335 calories. The unusually large values shown by this study led to a reduction in the amounts of food eaten, so that the winter dietary here reported, continuing for six weeks in February and March, showed but 186 grams of protein and 3,750 calories of energy in the daily food. The results obtained in the two weeks' study in the following May again show a marked decrease in both the protein and energy of the food consumed, the protein amounting to 130 grams per day, and the fuel value to 2,805 calories. In the summer study, carried on during two

weeks in August, there was a still further falling off in the amounts of protein and energy of the daily food, these amounting to but 85 grams and 2,280 calories respectively.

The smaller consumption of food during the spring and summer dietaries may be due to various circumstances. The subject himself attributes the decrease to two causes, warmer weather and his own decreased physical vigor. He was usually in poorer health in warm weather than in cold. Indeed he rarely passed a summer without succumbing, to a greater or less extent, to his disease. It seems probable that these two circumstances, and especially the decreased physical vigor, were the most important causes leading to a reduction in the amount of food consumed. A most fortunate improvement in his health since these studies were made, so marked indeed as to permit tolerably active occupation, implies that the reduction in the amounts of food could hardly have been injurious.

It would be wrong to omit an expression of appreciation of the spirit and the labor which have resulted in these valuable observations. Their author is Mr. Herbert Scholfield, who hesitated to permit the use of his name in the previous report, but now kindly consents.

OTHER STUDIES.

Two other studies were made by this same observer; one the dietary of a farmer's family (No. 203), the other (No. 224) that of two ladies, relatives of the observer, who were spending a short time with him. The dietary study of a private boarding house in Middletown, Conn., was conducted by Mr. D. W. Colby, the Secretary of the Station. The description of these three studies is given in connection with the statistics and tables on pages 140 and 144.

No. 184. DIETARY OF A MAN IN THE ADIRONDACK MOUNTAINS IN WINTER.

The study commenced February 1, 1897, and continued forty-two days, during which time 126 meals were eaten. The subject, a consumptive, was obliged to live permanently in the Adirondacks. He had been ill, at the time of the study, nearly seven years, during which period he had so far gotten the better of his disease that, except for inability to undergo hardships or heavy labor, his food consumption might be regarded as that of a man in ordinary health. His weight was 148 pounds. This is the same subject whose dietary in midwinter appeared in the Report of the Station for 1896 as No. 175.

For a further description of the circumstances attending the study, see pages 133–135.

TABLE 14.

Cost and weights of food materials used in dietary No. 184.

Food Materials.	Cost.	Weight. Pounds.	Weight. Ounces.	Food Materials.	Cost.	Weight. Pounds.	Weight. Ounces.
ANIMAL FOOD.	$			VEGETABLE FOOD.	$		
Beef.				Cracked wheat, -	.06	—	15.0
Sirloin, - - -	.14	1	6.0	Breakfast food, -	.05	—	12.0
Shoulder clod, - -	.38	7	10.0	Rolled oats, - -	.02	—	11.0
Round, - - -	1.99	14	8.0	Samp, - - -	.02	—	5.0
Rib roast, - -	.73	4	1.5	Flour, bread, - -	.32	12	5.0
Dried, - - -	.24	1	3.5	Flour, low grade, -	.08	3	—
Gelatine, - - -	.14	—	1.5	Crackers, oyster, -	.10	1	—
				Corn meal, - -	—	—	3.0
Mutton.				Rice, - - -	.05	—	9.0
Chops, loin, - -	.41	4	2.0	Sugar, - - -	.35	6	6.0
Side, - - -	2.25	22	—	Tapioca, - -	.02	—	3.0
				Cornstarch, - -	.02	—	3.0
Pork.				Chocolate, - -	.25	—	10.0
Salt, fat, - - -	—	—	.5	Beets, - - -	.06	1	3.0
Sausage, - - -	.01	—	2.0	Carrots, - - -	.01	—	7.0
				Onions, - - -	.05	1	9.0
Fish.				Peas, dried, - -	.02	—	10.5
Cod, - - -	.35	4	7.0	Potatoes, - -	.26	25	5.0
Flounder, - -	.10	1	—	Turnips, - -	.07	3	12.0
Haddock (24.5 % ref.),	.35	2	8.0	Tomatoes, canned, -	.19	3	2.0
Salmon, canned, -	.25	2	—	Apricots, - -	.16	2	3.0
Sardines, - - -	.02	—	1.5	Lemons, - -	.15	1	6.0
				Oranges, - -	.25	3	6.0
Poultry, Etc.				Prunes, dried, -	.14	1	2.0
Fowl, - - -	.43	2	6.0	Raisins, - - -	.01	—	1.5
Giblets, - - -	.04	—	3.0	Blueberries, canned,	.05	—	11.0
				Cranberries, - -	.10	—	13.0
Eggs, - - -	.76	5	9.0	Marmalade, - -	.45	2	13.0
Butter, - - -	.75	3	—	Raspberries, - -	.20	2	—
Milk, - - -	4.11	117	8.0	Total veg. food, -	3.51	77	10.0
Total animal food,	13.45	193	13.5	Total food, -	16.96	271	7.5

TABLE 15.

Weights and percentages of food materials and nutritive ingredients used in dietary study No. 184.

Kind of Food Materials.	Weight. Food Materials.	Weight. Nutrients. Protein.	Weight. Nutrients. Fat.	Weight. Nutrients. Carbohydrates.	Cost.	Percentages of Total Food. Food Materials.	Percentages of Total Food. Nutrients. Protein.	Percentages of Total Food. Nutrients. Fat.	Percentages of Total Food. Nutrients. Carbohydrates.	Cost.
Per Man per Day.	Gms.	Gms.	Gms.	Gms.	Cts.	%	%	%	%	%
Beef, veal, mutton, -	596	95	111	—	15.0	20.3	47.8	53.9	—	37.0
Pork, lard, etc., -	2	—	1	—	—	—	—	.5	—	—
Poultry, - - -	28	4	3	—	1.1	.9	2.1	1.4	—	2.8
Fish, etc., - -	108	15	2	—	2.5	3.7	7.7	.9	—	6.3
Eggs, - - -	60	7	6	—	1.8	2.1	3.6	2.8	—	4.5
Butter, - - -	32	—	27	—	1.8	1.1	—	12.8	—	4.4
Milk, - - -	1269	42	51	64	9.8	43.3	21.3	23.6	15.8	24.3
Total animal food,	2095	163	201	64	32.0	71.4	82.5	95.9	15.8	79.3
Cereals, - - -	213	25	4	159	1.7	7.3	12.6	2.0	39.5	4.1
Sugars and starches,	80	1	3	74	1.5	2.7	.4	1.5	18.5	3.8
Vegetables, - -	390	8	1	52	1.6	13.3	3.9	.3	12.9	3.9
Fruits, - - -	156	1	1	54	3.6	5.3	.6	.3	13.3	8.9
Total veg. food, -	839	35	9	339	8.4	28.6	17.5	4.1	84.2	20.7
Total food, - -	2934	198	210	403	40.4	100.0	100.0	100.0	100.0	100.0

TABLE 16.

Nutrients and potential energy, per man per day, in food purchased, rejected, and eaten in dietary study No. 184.

Kind of Food.	Weight and Fuel Value. Protein.	Weight and Fuel Value. Fat.	Weight and Fuel Value. Carbohydrates.	Weight and Fuel Value. Fuel Value.	Cost.	Percentages of Total Food. Protein.	Percentages of Total Food. Fat.	Percentages of Total Food. Carbohydrates.	Percentages of Total Food. Fuel Value.	Percentages of Total Food. Cost.
Food Purchased.	Gms.	Gms.	Gms.	Cal.	Cts.	%	%	%	%	%
Animal, - - -	163	201	64	2845	32.0	82.5	95.9	15.8	36.3	79.3
Vegetable, - -	35	9	339	1620	8.4	17.5	4.1	84.2	63.7	20.7
Total, - - -	198	210	403	4465	40.4	100.0	100.0	100.0	100.0	100.0
Waste.										
Animal, - - -	9	64	—	635	—	4.6	30.8	—	14.2	—
Vegetable, - -	3	—	—	80	—	1.3	—	.4	1.8	—
Total, - - -	12	64	—	715	—	5.9	30.8	.4	16.0	—
Food Actually Eaten.										
Animal, - - -	154	141	64	2210	—	77.9	65.1	15.8	22.1	—
Vegetable, - -	32	9	322	1540	—	16.2	4.1	83.8	61.9	—
Total, - - -	186	150	386	3750	—	94.1	69.2	99.6	84.0	—

No. 202. DIETARY OF A MAN IN THE ADIRONDACK MOUNTAINS IN SPRING.

The study began with breakfast on May 17th, and continued fourteen days. It was carried on by the same person as No. 175 in the Report for 1896 and Nos. 184 and 223 in this Report.

During the period covered the subject was "not quite as well" as during the previous study, but took "much more exercise" than during the period in February, 1896, or in February, 1897. This exercise was out of doors, chiefly fishing, and working in the garden. The temperature was unusually low for the time of year.

For further description of the circumstances attending the study, see pages 133–135.

Table 17.

Cost and weights of food materials used in dietary No. 202.

Food Materials.	Cost.	Weight.		Food Materials.	Cost.	Weight.	
		Pounds.	Ounces.			Pounds.	Ounces.
Animal Food.	$			Vegetable Food.	$		
Beef.				Wheat flour, - -	.09	3	5.0
Rib roast, - -	.49	2	—	Breakfast food, wheat	.04	—	7.5
Round steak, - -	.28	2	4.5	Rolled oats, - -	—	—	2.0
				Wheat bread, - -	.01	—	6.0
Cottolene, - -	—	—	.5	Macaroni, - -	.02	—	2.5
				Rice, - - -	.02	—	3.0
				Sugar, granulated, -	.06	1	2.5
Mutton.				Sugar, maple, -	.08	—	10.5
Chuck, lean, - -	.14	1	5.0	Cornstarch, - -	.01	—	2.0
Neck, - - -	.06	—	15.0	Chocolate, - -	.01	—	.5
Leg, - - -	.49	2	11.5	Cocoa, - - -	.01	—	.5
				Potatoes (19.27% ref.)	.04	4	2.0
Fish.				Tomatoes, canned, -	.10	1	8.5
				Peas, dried, - -	.01	—	5.0
Brook trout, - -	.08	—	5.0	Figs, - - -	.01	—	2.0
				Prunes, - - -	.08	—	8.5
Eggs, - - -	.11	2	7.0	Raisins, - - -	.01	—	1.0
Butter, - - -	.15	—	9.5				
Milk, - - -	1.24	40	13.5	Total veg. food, -	.60	13	5.0
Total animal food,	3.04	53	7.5	Total food, - -	3.64	66	12.5

TABLE 18.

Weights and percentages of food materials and nutritive ingredients used in dietary study No. 202.

Kind of Food Materials.	Weight. Food Materials.	Weight. Nutrients. Protein.	Weight. Nutrients. Fat.	Weight. Nutrients. Carbohydrates.	Cost.	Percentages of Total Food. Food Materials.	Percentages of Total Food. Nutrients. Protein.	Percentages of Total Food. Nutrients. Fat.	Percentages of Total Food. Nutrients. Carbohydrates.	Cost.
Per Man per Day.	Gms.	Gms.	Gms.	Gms.	Cts.	%	%	%	%	%
Beef, veal, mutton, -	299	55	58	—	10.4	13.8	41.3	41.9	—	40.1
Fish, etc., - -	10	2	—	—	.6	.5	1.4	.2	—	2.3
Eggs, - - -	80	9	8	—	.8	3.7	7.0	5.6	—	3.0
Butter, - - -	20	—	17	—	1.0	.9	.2	11.9	—	4.1
Milk, - - -	1322	44	53	66	9.0	61.2	32.7	38.3	23.3	34.1
Total animal food,	1731	110	136	66	21.8	80.1	82.6	97.9	23.3	83.6
Cereals, - - -	150	16	2	110	1.3	6.9	12.3	1.4	38.7	4.9
Sugars and starches,	64	—	1	59	1.2	3.0	.2	.4	20.8	4.7
Vegetables, - -	193	6	—	33	1.1	8.9	4.5	.2	11.6	4.1
Fruits, - - -	24	1	—	16	.7	1.1	.4	.1	5.6	2.7
Total veg. food, -	431	23	3	218	4.3	19.9	17.4	2.1	76.7	16.4
Total food, - -	2162	133	139	284	26.1	100.0	100.0	100.0	100.0	100.0

TABLE 19.

Nutrients and potential energy, per man per day, in food purchased, rejected, and eaten in dietary study No. 202.

Kind of Food.	Weight and Fuel Value. Protein.	Weight and Fuel Value. Fat.	Weight and Fuel Value. Carbohydrates.	Weight and Fuel Value. Fuel Value.	Cost.	Percentages of Total Food. Protein.	Percentages of Total Food. Fat.	Percentages of Total Food. Carbohydrates.	Percentages of Total Food. Fuel Value.	Percentages of Total Food. Cost.
Food Purchased.	Gms.	Gms.	Gms.	Cal.	Cts.	%	%	%	%	%
Animal, - - -	110	136	66	1985	21.8	82.6	97.9	23.3	66.2	83.6
Vegetable, - -	23	3	218	1015	4.3	17.4	2.1	76.7	33.8	16.4
Total, - - -	133	139	284	3000	26.1	100.0	100.0	100.0	100.0	100.0
Waste.										
Animal, - - -	3	20	—	200	—	2.3	14.4	—	6.7	—
Vegetable, - -	—	—	—	—	—	—	—	—	—	—
Total, - - -	3	20	—	200	—	2.3	14.4	—	6.7	—
Food Actually Eaten.										
Animal, - - -	107	116	66	1790	—	60.3	83.5	23.3	59.5	—
Vegetable, - -	23	3	218	1015	—	17.4	2.1	76.7	33.8	—
Total, - - -	130	119	284	2805	—	77.7	85.6	100.0	93.3	—

No. 203. DIETARY OF A FARMER'S FAMILY IN NEW YORK.

The study began May 6, 1897, and continued fourteen days. The members of the family were as follows: The husband, a healthy man of 32 years; the wife, 36 years of age; girl, 11 years of age; and boy, 10 years of age. There were also two boarders, a carpenter, 30 years old, his wife, 21 years old, and a farm hand, 21 years old.

The number of meals taken was as follows:

Three men, average weight, 147 lbs., - - - -	98 meals.
Two women, average weight 118 lbs. (82 x .8 meal of man), equivalent to - - - - - - -	66 meals.
Two children, average weight 75 lbs. (83 x .6 meal of man), equivalent to - - - - - - -	50 meals.
Visitors, - - - - - - - - - -	4 meals.
Total number of meals taken, equivalent to -	218 meals.

Equivalent to one man 73 days.

TABLE 20.

Cost and weights of food materials used in dietary No. 203.

Food Materials.	Cost.	Weight. Pounds.	Weight. Ounces.	Food Materials.	Cost.	Weight. Pounds.	Weight. Ounces.
Animal Food.	$			Vegetable Food.	$		
Beef.				Flour, wheat, - -	.98	34	6.0
Round, - - -	.47	3	11.5	Flour, graham, -	.03	1	1.5
Corned, canned, -	.11	—	9.0	Flour, buckwheat, -	.27	8	15.0
				Corn meal, - -	.04	1	5.0
Cottolene, - -	.29	2	14.0	Wheat, br'kfast food,	—	—	.5
				Rolled oats, - -	.07	2	6.0
				Rice, - - -	.03	—	5.5
Veal.				Bread, - - -	.13	3	3.5
Chops, - - -	.20	2	—	Cake, - - -	.12	1	9.0
Leg, - - -	.14	1	6.0	Crackers, Boston, -	.01	—	1.5
				Pie, apple, - -	.10	2	4.0
Pork.				Sugar, granulated, -	.69	13	2.0
Ham, - - -	.76	5	1.5	Sugar, maple, -	.06	—	8.0
Salt, fat, - - -	1.29	21	1.5	Molasses, - -	.05	1	15.0
				Syrup, - - -	.12	3	5.0
Fish.				Chocolate, - -	.08	—	2.5
Pickerel, - - -	.24	3	—	Beans, - - -	.10	3	12.0
Salmon, canned, -	.13	1	.5	Potatoes, - -	1.30	104	9.5
				Rhubarb, - -	.01	—	7.0
				Onions, - - -	.02	1	—
Eggs, - - -	1.63	19	2.0	Succotash, canned, -	.08	1	3.5
Milk, whole, - -	.71	23	11.5	Apples, - - -	.79	55	14.0
Milk, skimmed, -	.11	11	5.5	Apples, dried, -	.01	—	1.0
Milk, sour, - -	.32	10	9.5	Cranberries, canned,	.02	—	4.0
Cream, - - -	.79	3	7.0	Peaches, canned, -	.13	3	2.5
Buttermilk, - -	.05	3	1.5				
Butter, - - -	1.01	4	.5	Total veg. food, -	5.24	244	15.5
Total animal food,	8.25	116	1.5	Total food, - -	13.49	361	1.0

TABLE 21.

Weights and percentages of food materials and nutritive ingredients used in dietary study No. 203.

Kind of Food Materials.	Weight. Food Materials.	Weight. Nutrients. Protein.	Weight. Nutrients. Fat.	Weight. Nutrients. Carbohydrates.	Cost.	Percentages of Total Food. Food Materials.	Percentages of Total Food. Nutrients. Protein.	Percentages of Total Food. Nutrients. Fat.	Percentages of Total Food. Nutrients. Carbohydrates.	Cost.
Per Man per Day.	Gms.	Gms.	Gms.	Gms.	Cts.	%	%	%	%	%
Beef, veal, mutton, -	65	9	23	—	1.7	2.9	9.6	11.3	—	9.0
Pork, lard, etc., -	163	8	125	—	2.8	7.3	7.7	61.1	—	15.2
Fish, etc., - -	25	3	1	—	.5	1.1	3.3	.4	—	2.7
Eggs, - - -	119	14	12	—	2.2	5.3	14.3	5.7	—	12.1
Butter, - - -	25	—	21	—	1.4	1.1	.3	10.3	—	7.5
Milk, - - -	324	11	13	16	2.7	14.4	10.9	6.2	3.0	14.7
Total animal food,	721	45	195	16	11.3	32.1	46.1	95.0	3.0	61.2
Cereals, - - -	345	34	7	250	2.4	15.4	35.5	3.4	46.1	13.2
Sugars and starches,	118	1	1	107	1.4	5.3	.4	.2	19.8	7.4
Vegetables, - -	690	16	1	127	2.1	30.8	16.8	.7	23.4	11.2
Fruits, - - -	369	1	1	42	1.3	16.4	1.2	.7	7.7	7.0
Total veg. food, -	1522	52	10	526	7.2	67.9	53.9	5.0	97.0	38.8
Total food, - -	2243	97	205	542	18.5	100.0	100.0	100.0	100.0	100.0

TABLE 22.

Nutrients and potential energy, per man per day, in food purchased, rejected, and eaten in dietary study No. 203.

Kind of Food.	Weight and Fuel Value. Protein.	Weight and Fuel Value. Fat.	Weight and Fuel Value. Carbohydrates.	Weight and Fuel Value. Fuel Value.	Cost.	Percentages of Total Food. Protein.	Percentages of Total Food. Fat.	Percentages of Total Food. Carbohydrates.	Percentages of Total Food. Fuel Value.	Percentages of Total Food. Cost.
Food Purchased.	Gms.	Gms.	Gms.	Cal.	Cts.	%	%	%	%	%
Animal, - - -	45	195	16	2065	11.3	46.1	95.0	3.0	45.6	61.2
Vegetable, - -	52	10	526	2460	7.2	53.9	5.0	97.0	54.4	38.8
Total, - - -	97	205	542	4525	18.5	100.0	100.0	100.0	100.0	100.0
Waste.										
Animal, - - -	—	—	—	—	—	—	—	—	—	—
Vegetable, - -	7	1	53	255	—	6.7	.4	9.2	5.4	—
Total, - - -	7	1	53	255	—	6.7	.4	9.2	5.4	—
Food Actually Eaten.										
Animal, - - -	45	195	16	2065	—	46.1	95.0	3.0	44.3	—
Vegetable, - -	45	9	473	2205	—	47.2	4.6	87.8	50.3	—
Total, - - -	90	204	489	4270	—	93.3	99.6	90.8	94.6	—

Remarks.—The preceding family was of French-Canadian descent. The wife of the carpenter helped about the housework. The study was made during the busy planting season, and all were at more or less active work. The farm, which was worth about $2,000, was heavily mortgaged, but this mortgage was being slowly paid off. The income of the family was very considerably increased by the mother taking in washing during the summer months. Pork was usually consumed in much larger quantities than beef. Milk and eggs were very largely sold, the children at times being allowed little or no milk to drink.

No. 223. DIETARY OF A MAN IN THE ADIRONDACK MOUNTAINS IN SUMMER.

The subject of this study was the same as in dietaries Nos. 175 (1896 Report), 184, and 202. The study began August 9, 1897, and continued fourteen days with forty-two meals. The subject had been sick in July, which doubtless accounts in part for the smaller amounts of nutrients in the food eaten. His weight was 141 pounds. For further description, see pages 133–135.

TABLE 23.

Cost and weights of food materials used in dietary No. 223.*

FOOD MATERIALS.	Cost.	Weight.		FOOD MATERIALS.	Cost.	Weight.	
		Pounds.	Ounces.			Pounds.	Ounces.
ANIMAL FOOD.	$			VEG. FOOD.—(*Con.*)	$		
Beef.				Breakfast food,	.02	—	.5
Rib roast, fat,	.40	2	5.0	Rolled oats,	.03	—	6.5
Sirloin steak,	.02	—	3.0	Rice,	.01	—	1.0
Dried,	.06	—	4.5	Bread, white,	.03	—	12.0
				Sugar,	.08	1	6.0
Mutton.				Cornstarch,	—	—	.5
Loin, chops,	.03	—	4.0	Chocolate,	.01	—	.5
Neck,	.03	—	8.5	Cocoa,	.07	—	2.0
Leg,	.11	1	1.0	Beans, string,	.03	1	5.0
				Beets,	—	—	1.0
Poultry,	.11	—	10.0	Lettuce,	—	—	.5
				Peas, dried,	—	—	1.5
Fish.				Peas, green,	.02	1	2.0
Salt cod,	.02	—	3.5	Potatoes,	.05	4	13.5
				Squash,	.02	1	2.5
Eggs,	.08	—	10.5	Tomatoes, canned,	.05	—	13.0
Butter,	.20	—	13.0	Blueberries,	.02	—	14.5
Milk,	.77	25	13.0	Olives,	.01	—	1.0
Total animal food,	1.83	32	12.0	Oranges,	.01	—	4.0
				Raspberries,	.06	2	8.5
VEGETABLE FOOD.				Peaches, canned,	.01	—	2.5
Flour,	.05	1	14.5	Total veg. food,	.59	18	2.5
Cracked wheat,	—	—	1.0				
Macaroni,	.01	—	.5	Total food,	2.42	50	14.5

* All weights are of edible portion.

TABLE 24.

Weights and percentages of food materials and nutritive ingredients used in dietary study No. 223.

Kind of Food Materials.	Weight. Food Materials.	Nutrients. Protein.	Fat.	Carbohydrates.	Cost.	Percentages of Total Food. Food Materials.	Nutrients. Protein.	Fat.	Carbohydrates.	Cost.
Per Man per Day.	Gms.	Gms.	Gms.	Gms.	Cts.	%	%	%	%	%
Beef, veal, mutton, -	147	25	40	—	4.6	8.9	29.7	37.8	—	26.9
Pork, lard, etc., -	—	—	—	—	—	—	—	—	—	—
Poultry, - - -	20	4	3	—	.8	1.2	4.4	2.9	—	4.5
Fish, etc., - -	7	2	—	—	.2	.4	2.2	—	—	.8
Eggs, - - -	21	3	2	—	.6	1.3	3.3	2.1	—	3.3
Butter, - - -	26	—	22	—	1.4	1.6	.3	20.6	—	8.3
Cheese, - - -	—	—	—	—	—	—	—	—	—	—
Milk, - - -	836	28	34	42	5.5	50.6	32.5	31.2	18.3	31.8
Total animal food,	1057	62	101	42	13.1	64.0	72.4	94.6	18.3	75.6
Cereals, - - -	113	13	2	79	1.1	6.8	15.1	2.1	34.6	6.2
Sugars and starches,	51	1	2	47	1.1	3.1	1.3	1.5	20.6	6.7
Vegetables, - -	305	8	1	46	1.2	18.5	9.8	.7	19.9	7.0
Fruits, - - -	126	1	1	15	.8	7.6	1.4	1.1	6.6	4.5
Total veg. food, -	595	23	6	187	4.2	36.0	27.6	5.4	81.7	24.4
Total food, - -	1652	85	107	229	17.3	100.0	100.0	100.0	100.0	100.0

TABLE 25.

Nutrients and potential energy, per man per day, in food eaten in dietary study No. 223.

Kind of Food.	Weight and Fuel Value. Protein.	Fat.	Carbohydrates.	Fuel Value.	Cost.	Percentages of Total Food. Protein.	Fat.	Carbohydrates.	Fuel Value.	Cost.
Food Eaten.	Gms.	Gms.	Gms.	Cal.	Cts.	%	%	%	%	%
Animal, - - -	62	101	42	1365	13.1	72.4	94.6	18.3	59.9	75.6
Vegetable, - -	23	6	187	915	4.2	27.6	5.4	81.7	40.1	24.4
Total, - - -	85	107	229	2280	17.3	100.0	100.0	100.0	100.0	100.0

No. 224. DIETARY OF TWO WOMEN IN THE ADIRONDACKS IN SUMMER.

The study began August 9, 1897, and continued fourteen days, making a total of eighty-four meals, equivalent to one woman twenty-eight days, or one man twenty-two days.

The subjects were relatives of the gentleman the studies of whose dietaries have been given as No. 175 (1896 Report), and Nos. 184, 202, and 223 of this Report. The two women "had light exercise and were in good health. They ate rather more than they were accustomed to when at their city home." The average weight of the women was 105 pounds.

TABLE 26.

Cost and weights of food materials used in dietary No. 224*

Food Materials.	Cost.	Weight. Pounds.	Weight. Ounces.
ANIMAL FOOD.	$		
Beef.			
Rib roast, fat,	.62	3	7.0
Dried,	.08	—	6.5
Mutton.			
Loin, chops,	.05	—	7.0
Neck,	.07	1	6.0
Leg,	.30	3	—
Poultry,	.20	1	2.0
Fish.			
Salt cod,	.04	—	6.5
Eggs,	.13	—	15.5
Butter,	.66	2	10.0
Milk,	1.24	41	7.5
Total animal food,	3.39	55	4.0
VEGETABLE FOOD.			
Flour,	.20	7	5.5
Cracked wheat,	.01	—	1.5
Macaroni,	—	—	.5
Breakfast food,	.04	—	9.5
VEG. FOOD.—*(Con.)*	$		
Rolled oats,	.04	—	10.0
Rice,	.01	—	2.0
Bread, white,	.01	—	2.5
Sugar,	.09	1	10.0
Cornstarch,	—	—	.5
Chocolate,	.02	—	.5
Cocoa,	.12	—	3.5
Beans, string,	.06	2	13.5
Beets,	.01	—	13.5
Lettuce,	.02	—	11.0
Onions,	—	—	1.5
Peas, dried,	.01	—	2.5
Peas, green,	.04	2	1.0
Potatoes,	.08	7	11.0
Squash,	.06	3	14.0
Tomatoes, canned,	.08	1	4.0
Apples,	.02	1	—
Blueberries,	.06	2	4.5
Olives,	.04	—	1.5
Olive oil,	—	—	.5
Raspberries,	.13	5	.5
Crabapple m'malade,	.02	—	1.0
Peaches, canned,	.07	—	14.0
Strawberry jam,	.02	—	1.5
Total veg. food,	1.26	39	13.5
Total food,	4.65	95	1.5

* All weights are of edible portion.

TABLE 27.

Weights and percentages of food materials and nutritive ingredients used in dietary study No. 224.

Kind of Food Materials.	Weight. Food Materials.	Weight. Nutrients. Protein.	Weight. Nutrients. Fat.	Weight. Nutrients. Carbohydrates.	Cost.	Percentages of Total Food. Food Materials.	Percentages of Total Food. Nutrients. Protein.	Percentages of Total Food. Nutrients. Fat.	Percentages of Total Food. Nutrients. Carbohydrates.	Cost.
Per Woman per Day.	Gms.	Gms.	Gms.	Gms.	Cts.	%	%	%	%	%
Beef, veal, mutton, -	140	24	37	—	4.0	8.9	29.7	37.8	—	26.9
Poultry, - - -	18	3	3	—	.7	1.2	4.5	2.9	—	4.5
Fish, etc., - -	6	2	—	—	.1	.4	2.2	—	—	.8
Eggs, - - -	16	2	2	—	.5	1.3	3.3	2.1	—	3.3
Butter, - - -	43	1	36	—	2.4	1.6	.3	20.6	—	8.3
Milk, - - -	672	22	27	34	4.4	50.6	32.5	31.2	18.3	31.8
Total animal food,	895	54	105	34	12.1	64.0	72.5	94.6	18.3	75.6
Cereals, - - -	144	17	2	107	1.1	6.8	15.1	2.1	34.6	6.2
Sugars and starches,	32	1	1	29	.8	3.1	1.2	1.5	20.6	6.6
Vegetables, - -	316	8	1	43	1.3	18.5	9.8	.7	19.9	7.0
Fruits, - - -	153	1	2	20	1.3	7.6	1.4	1.1	6.6	4.6
Total veg. food, -	645	27	6	199	4.5	36.0	27.5	5.4	81.7	24.4
Total food, - -	1540	81	111	233	16.6	100.0	100.0	100.0	100.0	100.0

TABLE 28.

Nutrients and potential energy in food eaten in dietary study No. 224.

Kind of Food.	Weight and Fuel Value. Protein.	Weight and Fuel Value. Fat.	Weight and Fuel Value. Carbohydrates.	Weight and Fuel Value. Fuel Value.	Cost.	Percentages of Total Food. Protein.	Percentages of Total Food. Fat.	Percentages of Total Food. Carbohydrates.	Percentages of Total Food. Fuel Value.	Percentages of Total Food. Cost.
FOOD EATEN. *Per Woman per Day.*	Gms.	Gms.	Gms.	Cal.	Cts.	%	%	%	%	%
Animal, - - -	54	105	34	1340	12.1	72.5	94.6	18.3	57.8	75.6
Vegetable, - -	27	6	199	980	4.5	27.5	5.4	81.7	42.2	24.4
Total, - - -	81	111	233	2320	16.6	100.0	100.0	100.0	100.0	100.0
Calculated per Man per Day.										
Animal, - - -	67	131	42	1675	15.2	72.5	94.6	18.3	57.8	75.6
Vegetable, - -	34	8	249	1225	5.6	27.5	5.4	81.7	42.2	24.4
Total, - - -	101	139	291	2900	20.8	100.0	100.0	100.0	100.0	100.0

No. 226. DIETARY OF A PRIVATE BOARDING HOUSE IN MIDDLETOWN, CONN.

The study began October 12, 1897, and continued eight days. The members of the household consisted of six adults, five men between 23 and 43 years of age, and one woman about 33 years old. One of the men served as janitor in a public building; the occupation of the others was sedentary rather than active. The woman was engaged in active household duties. The number of meals taken was as follows:

Men, average weight 127 lbs., - - - - -	103 meals.
Woman, weight 135 lbs. (24 x .8 meal of man), equivalent to	19 meals.
Visitors (men), - - - - - - - -	3 meals.
Total number of meals taken equivalent to - -	125 meals.

Equivalent to one man 42 days.

Table 29.

Cost and weights of food materials used in dietary No. 226.

Food Materials.	Cost.	Weight. Pounds.	Weight. Ounces.
Animal Food.	$		
Beef.			
Shoulder as purchased,	.52	4	5.0
Roast, porterhouse, (9.6 % refuse),	.52	2	8.0
Sirloin steak, - -	.34	2	2.0
Sweetbread, - -	.12	—	8.0
Bologna sausage, -	.06	—	8.0
Frankfort sausage, -	.18	1	12.0
Lamb.			
Hind quarter, - -	.99	7	1.0
Chops (24.5 % refuse),	.13	—	15.0
Pork.			
Loin, - - - -	.06	—	9.0
Ham, smoked, - -	.11	1	.5
Bacon, side, - -	.09	—	10.0
Sausage, - - - -	.08	1	—
Lard, - - - -	.07	1	6.5
Lard dripping, - -	—	—	9.0
Poultry.			
Chicken, - - - -	1.05	5	2.5
Chicken, pressed, -	.27	—	9.5
Fish.			
Halibut steak, - -	.30	1	8.0
Lobster (45.3 % ref.),	.32	—	15.0
Eggs, - - - -	1.21	6	1.5
Butter, - - - -	.81	3	4.5
Cheese, - - - -	.07	—	8.0
Milk, - - - -	.28	9	5.0
Cream, - - - -	.06	—	8.0
Total animal food,	7.64	52	12.0

Food Materials.	Cost.	Weight. Pounds.	Weight. Ounces.
Vegetable Food.	$		
Rice, - - -	.03	—	6.0
Flour, bread, - -	.21	7	2.0
Flour, pastry, -	.08	2	8.0
Flour, graham, -	.03	1	3.0
Buckwheat prep., -	.03	—	9.0
Wheat, breakfast food	.02	—	4.0
Rolled oats, - -	.06	1	7.0
Bread, - - - -	.06	2	1.5
Bread, graham, -	.02	—	7.5
Gingerbr'd, molasses,	.03	—	5.0
Crackers, milk, -	.09	1	2.5
Sugar, - - -	.49	9	12.0
Sugar, brown, -	.02	—	3.0
Molasses, - -	.04	—	14.5
Syrup, - - - -	.03	—	12.0
Cornstarch, - -	.01	—	1.0
Beans, lima (35.6 % ref.)	.05	1	10.0
Potatoes (24.5 % ref.),	.23	11	4.0
Onions (7.5 % ref.), -	.03	1	8.0
Squash, - - -	.01	—	9.5
Swt. potatoes (14.5 % r.)	.20	9	15.0
Tomatoes, (12.9 % ref.)	.06	3	2.5
Apples, - - -	.05	5	3.5
Apricots, canned, -	.07	1	10.0
Bananas (19.1 % ref.),	.32	5	5.0
Cranberries, - -	.01	—	3.0
Grapes (34.3 % ref.),	.16	7	12.0
Lemons (46.0 % ref.),	.03	—	3.0
Peaches, canned, -	.05	1	4.0
Raisins, - - -	.01	—	2.0
Shredded cocoanut, -	.13	—	8.0
Celery, - - -	.07	—	8.0
Total veg. food, -	2.73	79	13.5
Total food, - -	10.37	132	9.5

TABLE 30.

Weights and percentages of food materials and nutritive ingredients used in dietary study No. 226.

Kind of Food Materials.	Weight. Food Materials.	Weight. Nutrients. Protein.	Weight. Nutrients. Fat.	Weight. Nutrients. Carbohydrates.	Cost.	Percentages of Total Food. Food Materials.	Percentages of Total Food. Nutrients. Protein.	Percentages of Total Food. Nutrients. Fat.	Percentages of Total Food. Nutrients. Carbohydrates.	Cost.
Per Man per Day.	Gms.	Gms.	Gms.	Gms.	Cts.	%	%	%	%	%
Beef, veal, mutton, -	213	37	35	—	6.8	14.8	36.8	25.3	—	27.6
Pork, lard, etc., -	56	4	36	—	1.0	3.9	4.5	26.5	—	3.9
Poultry, - - -	62	9	8	—	3.1	4.3	9.4	6.2	—	12.7
Fish, etc., - -	26	4	1	—	1.5	1.9	4.2	.7	—	6.0
Eggs, - - -	66	9	7	—	2.9	4.6	8.8	5.4	—	11.7
Butter, - - -	36	—	30	—	1.9	2.5	.4	22.5	—	7.8
Cheese, - - -	5	1	2	—	.2	.4	1.4	1.3	—	.7
Milk, - - -	106	4	5	5	.8	7.4	3.6	3.7	1.5	3.3
Total animal food,	570	68	124	5	18.2	39.8	69.1	91.6	1.5	73.7
Cereals, - - -	189	21	5	133	1.6	13.2	21.4	3.6	36.5	6.3
Sugars and starches,	126	—	—	121	1.4	8.8	.2	—	33.1	5.7
Vegetables, - -	308	7	1	59	1.5	21.5	6.6	.9	16.3	6.3
Fruits, - - -	239	3	5	46	2.0	16.7	2.7	3.9	12.6	8.0
Total veg. food, -	862	31	11	359	6.5	60.2	30.9	8.4	98.5	26.3
Total food, - -	1432	99	135	364	24.7	100.0	100.0	100.0	100.0	100.0

TABLE 31.

Nutrients and potential energy, per man per day, in food purchased, rejected, and eaten in dietary study No. 226.

Kind of Food.	Weight and Fuel Value. Protein.	Weight and Fuel Value. Fat.	Weight and Fuel Value. Carbohydrates.	Weight and Fuel Value. Fuel Value.	Cost.	Percentages of Total Food. Protein.	Percentages of Total Food. Fat.	Percentages of Total Food. Carbohydrates.	Percentages of Total Food. Fuel Value.	Percentages of Total Food. Cost.
Food Purchased.	Gms.	Gms.	Gms.	Cal.	Cts.	%	%	%	%	%
Animal, - - -	68	124	5	1455	18.2	69.1	91.6	1.5	46.1	73.7
Vegetable, - -	31	11	359	1700	6.5	30.9	8.4	98.5	53.9	26.3
Total, - - -	99	135	364	3155	24.7	100.0	100.0	100.0	100.0	100.0
Waste.										
Animal, - - -	3	4	—	50	—	3.4	2.9	.1	1.6	—
Vegetable, - -	1	1	6	40	—	1.0	.9	1.7	1.3	—
Total, - - -	4	5	6	90	—	4.4	3.8	1.8	2.9	—
Food Actually Eaten.										
Animal, - - -	65	120	5	1405	—	65.7	88.7	1.4	44.5	—
Vegetable, - -	30	10	353	1660	—	29.9	7.5	96.8	52.6	—
Total, - - -	95	130	358	3065	—	95.6	96.2	98.2	97.1	—

TABLE 32.

Summary of dietary studies made by the Station.

No. of Dietary.	Dietaries.	Nutrients. Protein.	Fat.	Carbo-hydrates.	Fuel Value.
	I.—DIETARY STUDIES AMONG FARMERS' FAMILIES.	Grams.	Grams.	Grams.	Cal.
	Two Dietaries of a Farmer's Family in Vermont.				
	December, 1895. (5)				
27	Food purchased and eaten, - - -	69	92	444	2960
	July, 1896. (6)				
174	Food purchased and eaten, - - -	89	117	449	3295
	Two Dietaries of a Farmer's Family in Connecticut.				
	December, 1894. (5)				
45	Food purchased and eaten, - - -	108	76	635	3755
	December, 1894. (5)				
46	Food purchased and eaten, - - -	109	91	608	3785
	Two Dietaries of a Farmer's Family in Connecticut.				
	October, 1895. (5)				
120	Food purchased, - - - - -	114	139	545	3995
	Food eaten, - - - - - -	100	121	501	3590
	April, 1896. (6)				
156	Food purchased, - - - - -	109	206	441	4170
	Food eaten, - - - - - -	94	177	406	3695
	Two Dietaries of a Farmer's Family in Connecticut.				
	October, 1895. (5)				
121	Food purchased and eaten, - - -	79	117	354	2865
	May, 1896. (6)				
157	Food purchased and eaten, - - -	96	139	356	3145
	Dietary of a Farmer's Family in Conn.				
	December, 1895. (5)				
123	Food purchased, - - - - -	140	174	456	4060
	Food eaten, - - - - - -	131	161	433	3810
	Dietary of a Farmer's Family in New York.				
	May, 1897. (7)				
203	Food purchased, - - - - -	97	205	542	4525
	Food eaten, - - - - - -	90	204	489	4270
	Average of 10 Dietaries of 6 Families.				
	Food purchased, - - - - -	**101**	**136**	**483**	**3655**
	Food eaten, - - - - - -	**97**	**130**	**467**	**3515**

TABLE 32.—*(Continued.)*

No. of Dietary.	Dietaries.	Nutrients. Protein.	Fat.	Carbo-hydrates.	Fuel Value.
	II.—DIETARY STUDIES AMONG MECHANICS' FAMILIES.	Grams.	Grams.	Grams.	Cal.
	Dietary of a Boarding House. October, 1890. (1)				
1	Food purchased,	126	188	426	4010
	Food eaten,	103	152	401	3490
	Dietary of a Blacksmith's Family. November, 1891. (2)				
4	Food purchased,	103	176	408	3730
	Food eaten,	100	171	401	3640
	Dietary of a Machinist's Family. November, 1891. (2)				
5	Food purchased,	100	159	427	3640
	Food eaten,	99	156	421	3580
	Two Dietaries of a Mason's Family. December, 1892. (2)				
6	Food purchased,	107	153	429	3620
	Food eaten,	104	148	413	3500
	April, 1893. (3)				
10	Food purchased,	125	145	366	3365
	Food eaten,	119	137	348	3190
	Dietary of a Carpenter's Family. December, 1892. (2)				
7	Food purchased,	125	152	498	3970
	Food eaten,	114	135	475	3670
	Two Dietaries of a Carpenter's Family. December, 1892. (2)				
8	Food purchased,	107	161	408	3610
	Food eaten,	100	149	388	3390
	May, 1893. (3)				
11	Food purchased,	115	125	346	3055
	Food eaten,	111	122	336	2965
	Dietary of a Carpenter's Family. November, 1894. (4)				
21	Food purchased,	104	118	471	3455
	Food eaten,	101	110	470	3365
	Average of 9 Dietaries of 7 Families.				
	Food purchased,	**113**	**153**	**420**	**3605**
	Food eaten,	**106**	**142**	**406**	**3420**

TABLE 32.—*(Continued.)*

No. of Dietary.	Dietaries.	Nutrients. Protein.	Fat.	Carbo-hydrates.	Fuel Value.
	III.—DIETARY STUDIES AMONG PROFESSIONAL MEN'S FAMILIES.	Grams.	Grams.	Grams.	Cal.
	Dietary of a Chemist's Family.				
	April, 1891. (1)				
2	Food purchased and eaten,	118	103	430	3210
	Dietary of a Jeweler's Family.				
	September, 1891. (2)				
3	Food purchased,	91	126	483	3530
	Food eaten,	83	117	478	3390
	Three Dietaries of Station Agriculturist's Family.				
	January, 1893. (3)				
9	Food purchased,	106	145	405	3450
	Food eaten,	99	139	398	3335
	July, 1893. (3)				
13	Food purchased,	133	150	475	3885
	Food eaten,	129	145	472	3800
	November, 1895. (6)				
169	Food purchased,	105	108	435	3220
	Food eaten,	104	105	433	3180
	Dietary of Three Chemists.				
	October, 1894. (4)				
20	Food purchased,	121	166	551	4300
	Food eaten,	116	158	535	4140
	Three Dietaries of a Chemist's Family.				
	November, 1895. (5)				
26	Food purchased,	104	122	385	3140
	Food eaten,	102	98	378	2880
	February, 1895. (5)				
28	Food purchased and eaten,	91	150	399	3405
	April, 1895. (5)				
29	Food purchased,	124	155	414	3650
	Food eaten,	122	147	410	3550
	Average of 9 Dietaries of 5 Families.				
	Food purchased,	**110**	**136**	**442**	**3530**
	Food eaten,	**107**	**129**	**437**	**3430**
	IV.—DIETARY STUDIES OF STUDENTS' CLUBS.				
	Dietary of a College Students' Club.				
	April, 1893. (3)				
12	Food purchased,	113	180	376	3680
	Food eaten,	94	141	346	3110

TABLE 32—(*Continued.*)

No. of Dietary.	Dietaries.	Nutrients. Protein.	Fat.	Carbo-hydrates.	Fuel Value.
		Grams.	Grams.	Grams.	Cal.
	Dietary of a College Students' Club. February, 1894. (4)				
16	Food purchased,	113	160	343	3360
	Food eaten,	104	136	326	3030
	Dietary of a Divinity School Club. March, 1894. (4)				
17	Food purchased,	138	185	356	3745
	Food eaten,	122	138	317	3085
	**Dietary of College Ladies' Eating Club. April, 1894. (4)*				
18	Food purchased,	135	196	377	3920
	Food eaten,	105	160	330	3270
	Dietary of a College Students' Club. November, 1895. (5)				
124	Food purchased,	137	186	557	4575
	Food eaten,	104	156	494	3900
	Average of Five Dietaries as above.				
	Food purchased,	**127**	**181**	**402**	**3880**
	Food eaten,	**106**	**146**	**363**	**3305**
	V.—UNCLASSIFIED DIETARY STUDIES.				
	Dietary of a Widow's Family. February, 1894. (4)				
14	Food purchased,	119	115	512	3655
	Food eaten,	116	111	500	3555
	Two Dietaries of a Swede Family. February, 1894. (4)				
15	Food purchased,	121	116	486	3565
	Food eaten,	118	112	479	3490
	October, 1894. (4)				
19	Food purchased,	137	129	651	4440
	Food eaten,	133	123	636	4300
	Dietary of a Laborer's Family. Winter of 1894-95. (6)				
23	Food purchased,	87	76	510	3155
	Food eaten,	87	75	509	3140
	Dietary of a Laborer's Family. December, 1894. (6)				
24	Food purchased,	109	102	434	3175
	Food eaten,	108	100	432	3145
	Dietary of a Private Boarding House. October, 1896. (6)				
173	Food purchased,	96	133	343	3035
	Food eaten,	92	119	339	2875

TABLE 32.—*(Continued.)*

No. of Dietary.	DIETARIES.	Protein.	Fat.	Carbo-hydrates.	Fuel Value.
		NUTRIENTS.			
	**Dietary of Two Women in the Adirondacks. August, 1897. (7)*	Grams.	Grams.	Grams.	Cal.
224	Food purchased, - - - - - -	104	144	298	2990
	Food eaten, - - - - - - -	101	139	291	2900
	Dietary of a Private Boarding House. October, 1897. (7)				
226	Food purchased, - - - - - -	99	135	364	3155
	Food eaten, - - - - - - -	95	130	358	3065
	Average of Eight Dietaries as above.				
	Food purchased, - - - - - -	**109**	**120**	**449**	**3400**
	Food eaten, - - - - - - -	**106**	**114**	**443**	**3310**
	Average of Forty-one Dietaries as above.				
	Food purchased, - - - - - -	**110**	**142**	**444**	**3590**
	Food eaten, - - - - - - -	**104**	**131**	**430**	**3410**
	VI.—MISCELLANEOUS DIETARY STUDIES.				
	Dietary of a Man in the Adirondacks. February, 1896. (6)				
175	Food eaten, - - - - - - -	200	216	367	4335
	February, 1897. (7)				
184	Food purchased, - - - - - -	198	210	403	4465
	Food eaten, - - - - - - -	186	150	386	3750
	May, 1897. (7)				
202	Food purchased, - - - - - -	133	139	284	3000
	Food eaten, - - - - - - -	130	119	284	2805
	August, 1897. (7)				
223	Food eaten, - - - - - - -	85	107	229	2280
	Average of Four Dietaries as above.				
	Food eaten, - - - - - - -	150	148	317	3290
	Dietary of a Camping Party in Maine.				
176	Food purchased, - - - - - -	172	261	533	5320
	Dietary of Sandow, "the Strong Man." January, 1896. (6)				
179	Food eaten, - - - - - - -	244	151	502	4462

* Calculated per man per day.

(1) Report of this Station, 1891, pp. 90–106. *(2) Ibid*, 1892, pp. 135–162. *(3) Ibid*, 1893, pp. 174–190. *(4) Ibid*, 1894, pp. 174–201. *(5) Ibid*, 1895, pp. 129–170. *(6) Ibid*, 1896, pp. 117–162. *(7)* This Report, pp. 130–153.

SUMMARY OF THE RESULTS OF DIETARY STUDIES REPORTED BY THE STATION.

Table 32 above gives a summary of the results of forty-seven dietary studies reported in the present and previous Annual Reports of this Station. These are for convenience arranged in six groups: those of farmers' families, those of mechanics' families, those of the families of professional men, those of College students' clubs, those which though normal do not naturally come into either of the above classes, and finally those which are more or less unusual or abnormal, and cannot be averaged with other studies. For the sake of comparison the average of each group but the last is given.

The results are in all cases calculated to the same basis, "per man per day." Accordingly the figures for the College ladies' club (No. 18) and for the two women in the Adirondacks (No. 224) represent larger quantities than were actually consumed. If they are multiplied by 0.8, the results will be the values "per woman per day," and will represent the amounts actually consumed in these two studies.

In each dietary the nutrients and fuel value, "per man per day," of the food purchased and eaten, are shown.

The averages for the food consumption in the various groups of dietary studies, as shown in the preceding summary, are briefly compared in the following table:

TABLE 33.

Comparison of the average food consumption of people with different occupation.

		Protein.	Fat.	Carbo-hydrates.	Fuel Value.
Per Man per Day.		Grams.	Grams.	Grams.	Grams.
Farmers' families (10),	Food purchased,	101	136	483	3655
	Food eaten, -	97	130	467	3515
Mechanics' families (9),	Food purchased,	113	153	420	3605
	Food eaten, -	106	142	406	3420
Professional men's families (9), - - -	Food purchased,	110	136	442	3530
	Food eaten, -	107	129	437	3430
College clubs (5), - -	Food purchased,	1[illegible]7	181	402	3880
	Food eaten, -	106	146	363	3305
Unclassified (8), - -	Food purchased,	109	120	449	3400
	Food eaten, -	106	114	443	3310
Average of all (41), -	Food purchased,	110	142	444	3590
	Food eaten, -	104	131	430	3410

EXPERIMENTS ON THE DIGESTION OF FOOD BY MAN.

REPORTED BY W. O. ATWATER AND F. G. BENEDICT.

The observations here reported are in continuation of those described in the previous reports of the Station, and especially in the Report for 1896, pages 163–180. They belong to a series of metabolism experiments with the respiration calorimeter, described beyond, in which the income and outgo of the body of man was measured. These metabolism experiments usually continued for a period of eight days, and were divided into two periods of four days each, the food being uniform during the eight days. The kinds and amounts of food were in general such as had been previously found to suffice the needs of the subject.

The first period was preliminary, the object being to bring the body into approximate equilibrium with the food. A reasonably close approximation to nitrogen equilibrium was generally reached at the end of the first period, as was shown by comparison of the nitrogen in food, feces, and urine. During this preliminary period the subject was generally in the laboratory or at his home, but the effort was made to have his muscular activity similar in amount to that of the second period. In experiment No. 37 the preliminary period was eight and in No. 39 it was five days instead of four. During the second period, which continued four days and five nights, the subject was in the chamber of the respiration calorimeter, and the nitrogen, carbon, hydrogen and energy of income and outgo were determined.

Subject.—All of the experiments were made with the same person, a laboratory assistant, a man in good health, thirty years of age, and weighing not far from 147 pounds without clothing.

Methods.—The general plan of the experiments was the same as previously described.* The methods of analysis were those

* Report of this Station for 1896, page 163. See also Bulletin 21 of the Office of Experiment Stations, U. S. Department of Agriculture, on Methods and Results of Investigations on the Chemistry and Economy of Food, pages 57-60.

ordinarily followed in this laboratory.* For supper of the day previous to the commencement of each experiment charcoal was given, usually with bread and milk, in order to separate the feces of the food preceding the experiment from those of the experiment proper. At the end of each experiment another separation was made, charcoal being given with milk and bread for either the supper of the last day of the experiment or the breakfast of the day following.

Heats of combustion. Fuel values.—Specimens of the dried food, feces, and residue from the evaporation of the urine were burned in the bomb calorimeter.† The results are designated as "heats of combustion, determined." The differences between the heats of combustion of food and feces is taken as the heat of combustion of the food which was actually utilized by the body for the building and repair of tissue and yielding of energy. These quantities are assumed to represent the available ingredients of the food. The term digestible is commonly applied to this material, but for reasons referred to beyond, the word available seems more appropriate.

Assuming that the body neither gains nor loses protein, fats or carbohydrates, these available materials or their equivalent will be burned in the body. The carbohydrates and fats are assumed to be completely oxidized, and hence their fuel value is taken as equivalent to their heats of combustion. The oxidation of the protein compounds, however, is not complete. Their nitrogen, in combination with hydrogen, oxygen and other elements, is excreted by the kidneys in various compounds, of which the most important is urea. If the heat of combustion of this unoxidized residue is subtracted from the total heat of combustion of the protein, the remainder is assumed to represent the amount of energy of the protein which has been made available to the body and is taken as a measure of the fuel value of the protein. Thus in digestion experiment No. 37, page 159, the total energy—*i. e.*, the heat of combustion—of the food eaten was 21,384 calories. The heat of combustion of the corresponding feces was 1,052 calories, leaving 20,332 calories as the measure of the heat of

* See Report of this Station for 1891, p. 47.

† This apparatus and the method of its use are described in the Report of this Station for 1894, page 135, and a later article in the present Report.

combustion of the food which was available to the body. The dried residue of the corresponding urine yielded 1,118 calories, so that the net energy which was made available to the body from the food was 19,214 calories. In other words the heat of combustion of the total food was 21,384 calories. That of the total available food was 20,332 and that of the net available food, which represents its actual fuel value, was 19,214 calories.

In this view the actual or net fuel value of the food is the heat of combustion of that portion which is actually oxidized (or capable of being oxidized) in the body. It is the heat of combustion of the total food less the sum of the heats of combustion of the unoxidized residues of feces and urine; the very small amounts of oxidizable materials in the products of respiration and perspiration and the volatile organic compounds eliminated by the intestine being left out of account. For the carbohydrates and fats the actual fuel values are the same as the heats of combustion of the amounts actually available to the body for building and repair and for the yielding of kinetic energy. These amounts are those commonly called "digestible" and estimated as equivalent to the total amounts in the food less those eliminated in the undigested food residues and the metabolic food products of the feces. The actual or net fuel value of the protein is the heat of combustion of the available (so-called "digestible") protein less the heat of combustion of the unoxidized residues of protein excreted in the urine.

The methods used for the determination of the heat of combustion of the urine deserve special mention, and will be discussed in another place. It will suffice to say here that the urine was evaporated on the so-called filter blocks of cellulose described by Kellner.*

DIGESTIBILITY VS. AVAILABILITY OF FOOD MATERIALS.

Frequent reference has been made in previous Reports to the fact that this method of experimenting does not show the proportions of a food material actually digested, since the feces contain, in addition to the undigested residue of the food, considerable quantities of other materials, the so-called metabolic products. These latter consist chiefly of residues of the bile

* Landw. Versuch-Stationen, Vol. 47, 1896, pp. 296, 297.

and mucus, and the gastric, pancreatic and other digestive secretions, but they include other materials, as epithelial debris from the intestinal walls. Recent investigation indicates very clearly that in man the undigested residues make a smaller and the metabolic products a much larger proportion of the intestinal secretion than has formerly been supposed. Thus the digestibility of most animal and many vegetable foods is found to be very nearly complete.* Prausnitz suggests very appositely that what we have to consider here is not so much the digestibility of the food—*i. e.*, the proportion of nutrients digested from a given material—as the amount of digestive juices used to render it capable of absorption from the alimentary canal. In other words, with ordinary diet the metabolic products make so large a part of the intestinal excreta that the amount of the latter depends more upon the quantity of digestive secretions needed to digest the particular kind of food than upon the quantity of undigested residue. Exceptions to this rule may be found where some of the coarser vegetable foods, as for instance, unbolted flours and meals, are used.

To determine the exact quantities of the food and nutrients actually digested it would be necessary to find the amount of undigested food residue in the feces, to determine the amounts of the several nutrients therein, and to subtract the undigested residue of each nutrient from the total amount of the latter in the food eaten. Numerous attempts have been made to elaborate methods for quantitative separation of the undigested food residues and the metabolic products of the intestinal secretions. While much valuable work has been done in this line the methods are not as yet as perfect as might be desired, and most investigators continue to follow the ordinary plan of taking the difference between the food and feces as the measure of the digestibility of the food.

The error here is, however, not so great as might be supposed. The metabolic products represent material which, for the most part, has been used for the purposes of the digestion. In other words, they are not available to the body for the yielding of energy, nor can they be utilized for building tissue

*See especially the late investigations by Prausnitz, Hammerl, Kermauer and Moeller, Ztschr. Biol. 35, *passim*.

or protecting it from waste. They are, therefore, unable to perform the principal functions of food. In the sense that they are not available for either building or repair of body material or for the yielding of energy, it is not improper to class them with the undigested residue of the food. This is equivalent to saying that the difference between the feces and food may be taken as measuring the amount which is actually available to the body for the main purposes of nutrition. Viewing the subject in this light and using the term digestibility in the sense of availability, the proportion of the food which is digested will be its total amount, less the sum of the undigested residues and the metabolic products which are involved in the digestive process. This is practically equivalent to the current method and is the plan followed in the experiments here described.

The subject demands much fuller discussion than can be given here, especially in the light of recent inquiry by Prausnitz and others. It will suffice here to insist upon the general fact that what is commonly called the digestibility of foods in experiments of this sort might be more properly designated as availability, reserving the detailed discussion for another place.

Collection of urine. Nitrogen lag.—In every instance the urine was collected in 24-hour periods, beginning and ending with 7 A. M., the amount passed at 7 A. M. being included in that of the twenty-four hours then ending. Of course the urine thus collected during a period of twenty-four hours does not represent the nitrogen metabolized in the body during that period, since a longer or shorter time elapses between the breaking down of nitrogenous compounds in the body and the excretion of the final nitrogenous products. This so-called nitrogen lag was referred to in a previous discussion.* For the main purpose of these experiments, namely, the determination of the income and outgo of matter and energy in the second period, the nitrogen lag is believed to be mainly if not entirely eliminated by the maintaining of a uniform diet through both periods. At the same time it is to be observed that the amount of nitrogen eliminated during the first day after the subject entered the calorimeter was sometimes larger or smaller than during the preceding or succeeding days.

* See Report of this Station for 1896, p. 102. Also Bulletin No. 44 of the Office of Experiment Stations of the U. S. Department of Agriculture, on Preliminary Experiments on the Metabolism of Nitrogen and Carbon in the Human Organism, p. 35.

DIGESTION EXPERIMENT NO. 37.

Kind of food: Mixed diet. *Subject:* Laboratory janitor (E. O.). *Weight* (with clothes): At beginning, 69.3 kilos; at end, 69.3 kilos. *Duration:* Eight days, with twenty-four meals.

TABLE 34.

Lab. No. of Sample.	Food Materials.	Weight of Material.	Total Organic Matter.	Protein. N.×6.25.	Fat.	Carbo-hydrates.	Ash.	Heats of Combustion. Determined.
		Gr.	Gr.	Gr.	Gr.	Gr.	Gr.	Cal.
2782	Beef, fried, - - -	960	328	275	53	—	17	2024
2783	Beef, dried, - - -	200	65	49	16	—	15	406
2781	Eggs, - - - -	846	200	107	93	—	8	1504
2785	Butter, - - - -	280	250	3	247	—	7	2254
2784	Milk, - - - -	6200	861	223	334	304	48	5524
2802	Bread, rye, - - -	2600	1417	224	8	1185	41	6286
2786	Sugar, - - - -	280	280	—	—	280	—	1110
2780	Beans, baked, - -	1000	291	79	6	206	22	1342
2779	Pears, canned, - -	1200	243	4	11	228	3	934
	Total, - - -	13566	3935	964	768	2203	161	21384
2805	Feces, - - - -	778	160	70	46	44	40	1052
—	Am't (digested) available,	—	3775	894	722	2159	121	20332
			%	%	%	%	%	
—	Per cent. available, - -	—	95.9	92.7	94.0	98.0	75.2	—
—	Estimated heats of combustion of urine, - -	—	—	—	—	—	—	1118
—	Energy of food oxidized in the body, - - -	—	—	—	—	—	—	19214
								%
—	Per cent. energy available,	—	—	—	—	—	—	89.9

Remarks.—This experiment, which represents the preliminary period of metabolism experiment No. 5, began with breakfast April 26, 1897. It differs from most of the digestion experiments in continuing eight days instead of four. The subject was engaged in his usual duties, which were not arduous. He might be considered in this case as having light muscular exercise. The following table shows the income and outgo of nitrogen in this experiment:

Income and outgo of nitrogen in digestion experiment No. 37.

Period.	Weight of Urine.	Nitrogen in Urine.		Nitrogen in Feces.	Nitrogen in Food.	Gain + or Loss —	
						Nitrogen.	Protein. N.×6.25.
1897.	Grams	Per Ct.	Grams.	Grams	Grams	Grams.	Grams.
April 26–27, 7 A. M.–7 A. M.,	948	1.57	14.9	1.4	19.3	+3.0	+18.7
April 27-28, 7 A. M.–7 A. M.,	978	1.82	17.8	1.4	19.2	.0	.0
April 28–29, 7 A. M.–7 A. M.,	1070	1.68	18.0	1.4	19.3	— .1	— .6
April 29–30, 7 A. M.–7 A. M.,	1140	1.78	20.3	1.4	19.2	—2.5	—15.6
April 30–May 1, 7 A.M.–7 A.M.,	1062	1.62	17.2	1.4	19.3	+ .7	+ 4.4
May 1–2, 7 A. M.–7 A. M.,	1050	1.68	17.6	1.4	19.2	+ .2	— 1.2
May 2–3, 7 A. M.–7 A. M.,	956	1.49	14.2	1.4	19.3	+3.7	+23.1
May 3–4, 7 A. M.–7 A. M.,	1445	1.65	23.8	1.4	19.2	—6.0	—37.5
Total, - - -	8649	—	143.8	11.2	154.0	—1.0	— 6.3

DIGESTION EXPERIMENT NO. 38.

Kind of food: Mixed diet. *Subject:* Laboratory janitor (E. O.). *Weight* (with clothes): At beginning, 69.3 kilos; at end, 68.8 kilos. *Duration:* Four days, with twelve meals.

TABLE 35.

Lab. No. of Sample.	FOOD MATERIALS.	Weight of Material.	Total Organic Matter.	Protein. N. × 6.25.	Fat.	Carbohydrates.	Ash.	Heats of Combustion. Determined.
		Gr.	Gr.	Gr.	Gr.	Gr.	Gr.	Cal.
2782	Beef, fried, - - -	480	164	138	26	—	8	1012
2783	Beef, dried, - - -	100	33	25	8	—	8	203
2781	Eggs, - - - - -	381	90	48	42	—	4	677
2785	Butter, - - - - -	140	125	1	124	—	4	1127
2784	Milk, - - - - -	3100	431	112	167	152	24	2764
2802	Bread, rye, - - -	1300	709	112	4	593	20	3143
2786	Sugar, - - - - -	140	140	—	—	140	—	555
2780	Beans, baked, - -	500	145	39	3	103	11	671
2779	Pears, canned, - -	600	121	2	5	114	1	467
	Total, - - -	6741	1958	477	379	1102	80	10619
2806	Feces, - - - -	502	90	41	23	26	20	573
—	Am't (digested) available,	—	1868	436	356	1076	60	10046
			%	%	%	%	%	
—	Per cent. available, - -	—	95.4	91.4	93.9	97.6	75.0	—
—	Estimated heat of combustion of urine, - -	—	—	—	—	—	—	493
—	Energy of food oxidized in the body, - - -	—	—	—	—	—	—	9553
								%
—	Per cent. energy available,	—	—	—	—	—	—	90.0

Remarks.—This experiment began with breakfast May 4, 1897. It represents the second period of metabolism experiment No. 5, namely, that passed in the respiration calorimeter. The subject entered the calorimeter on the evening of May 3 and remained until 7 o'clock on the morning of May 8, when the experiment ended. The separation of the feces was made with supper on May 3, the close of experiment No. 37. Consequently one separation marks the end of the first and the beginning of the second period of the metabolism experiment. The following table shows the income and outgo of nitrogen in this experiment.

Income and outgo of nitrogen in digestion experiment No. 38.

PERIOD.	Weight of Urine.	Nitrogen in Urine.		Nitrogen in Feces.	Nitrogen in Food.	GAIN + OR LOSS —	
						Nitrogen.	Protein. N.×6 25.
1897.	Grams.	Per Ct.	Grams.	Grams	Grams.	Grams.	Grams.
May 4–5, 7 A. M.–7 A. M.,	2088	.97	20.3	1.6	19.1	—2.8	—17.5
May 5–6, 7 A. M.–7 A. M.,	2293	.76	17.4	1.7	19.0	— .1	— .6
May 6–7, 7 A. M.–7 A. M.,	2243	.77	17.2	1.6	19.1	+ .3	+ 1.9
May 7–8, 7 A. M.–7 A. M.,	2497	.70	17.4	1.7	19.0	— .1	— .6
Total, - - -	9121	—	72.3	6.6	76.2	—2.7	—16.8

DIGESTION EXPERIMENT NO. 39.

Kind of food: Mixed diet. *Subject:* Laboratory janitor (E. O.). *Weight* (without clothes): At beginning, 68.6 kilos; at end, 66.2 kilos. *Duration:* Four days, with twelve meals.

TABLE 36.

Lab. No. of Sample.	Food Materials.	Weight of Material.	Total Organic Matter.	Protein. N. × 6.25.	Fat.	Carbohydrates.	Ash.	Heats of Combustion. Determined.
		Grams	Grams	Grams	Grams	Grams	Grams	Cal.
2789	Beef, fried,	400	154	119	35	—	8	968
2788	Ham, deviled,	210	112	35	77	—	9	914
2790	Eggs,	208	53	29	24	—	2	401
2793	Butter,	300	265	3	262	—	7	2386
2799	Milk,	3400	476	102	184	190	24	3178
2803	Bread, white,	1800	988	149	29	810	22	4572
2786	Sugar,	200	200	—	—	200	—	793
2791	Beans, baked,	500	134	36	2	96	9	611
2792	Pears, canned,	1200	221	4	2	215	3	911
	Total,	8218	2603	477	615	1511	84	14734
2807	Feces,	487	112	47	29	36	23	768
—	Am't (digested) available,	—	2491	430	586	1475	61	13966
			%	%	%	%	%	
—	Per cent. available,	—	95.7	90.1	95.3	97.6	72.6	—
—	Estimated heat of combustion of urine,	—	—	—	—	—	—	538
—	Energy of food oxidized in the body,	—	—	—	—	—	—	13428
								%
—	Per cent. energy available,	—	—	—	—	—	—	91.2

Remarks.—This experiment, which represents the preliminary period of metabolism experiment No. 6, began with breakfast May 14, 1897, and continued four days. The subject was at work several hours each day on a bicycle, either riding over country roads or working a stationary machine indoors. His work was probably harder than that to which he was accustomed. The amount of protein in the food per day was the same as in the preceding experiment, but the fuel value was largely increased. The following table shows the income and outgo of nitrogen. The urine for the first day was discarded as it appeared to be abnormal.

Income and outgo of nitrogen in digestion experiment No. 39.

Period.	Weight of Urine.	Nitrogen in Urine.		Nitrogen in Feces.	Nitrogen in Food.	Gain + or Loss —	
						Nitrogen.	Protein. N.×6.25.
1897.	Grams.	Per Ct.	Grams.	Grams	Grams.	Grams.	Grams.
May 15–16, 7 A. M.–7 A. M.,	771	1.59	12.3	1.9	19.1	+ 4.9	+30.6
May 16–17, 7 A. M.–7 A. M.,	734	1.40	10.3	1.9	19.1	+ 6.9	+43.1
May 17–18, 7 A. M.–7 A. M.,	1728	.91	15.7	1.9	19.1	+ 1.5	+ 9.4
Total,	3233	—	38.3	5.7	57.3	+13.3	+83.1

DIGESTION EXPERIMENT NO. 40.

Kind of food: Mixed diet. *Subject:* Laboratory janitor (E. O.). *Weight* (without clothes): At beginning, 66.2 kilos; at end, 66.7 kilos. *Duration:* Four days, with twelve meals.

TABLE 37.

Lab. No. of Sample.	FOOD MATERIALS.	Weight of Material.	Total Organic Matter.	Protein. N. × 6.25.	Fat.	Carbo-hydrates.	Ash.	Heats of Combustion. Determined.
		Grams	Grams	Grams	Grams	Grams	Grams	Cal.
2789	Beef, fried, - - -	400	154	119	35	—	9	968
2788	Ham, deviled, - -	200	107	33	74	—	8	871
2790	Eggs, - - - - -	216	54	30	24	—	2	416
2793	Butter, - - - - -	300	265	3	262	—	7	2386
2799	Milk, - - - - -	3400	476	102	184	190	24	3179
2803	Bread, white, - - -	1800	259	149	29	810	22	4572
2786	Sugar, - - - - -	200	200	—	—	200	—	793
2791	Beans, baked, - -	500	134	36	2	96	9	611
2792	Pears, canned, - -	1200	221	4	2	215	3	911
	Total, - - - -	8216	1870	476	612	1511	84	14707
2808	Feces, - - - - -	465	82	37	19	26	17	555
—	Am't (digested) available,	—	1788	439	593	1485	67	14152
			%	%	%	%	%	
—	Per cent. available, - -	—	95.6	92.2	96.9	98.3	79.8	—
—	Estimated heat of combustion of urine, - -	—	—	—	—	—	—	540
—	Energy of food oxidized in the body, - - -	—	—	—	—	—	—	13612
								%
—	Per cent. energy available,	—	—	—	—	—	—	92.6

Remarks.—This experiment began with breakfast May 18 and continued four days. It represents the second period of metabolism experiment No. 6, namely, that passed in the respiration calorimeter. The subject entered the calorimeter on the evening of May 17, immediately after the close of the first period, and remained until 7 o'clock on the morning of May 21. The charcoal taken with the bread and milk for supper May 17 served to mark the separation of the feces between the end of the first and the beginning of the second period of this metabolism experiment. The following table shows the income and outgo of nitrogen:

Income and outgo of nitrogen in digestion experiment No. 40.

PERIOD.	Weight of Urine.	Nitrogen in Urine.*		Nitrogen in Feces.	Nitrogen in Food.	GAIN + OR LOSS —	
						Nitro-gen.	Protein. N.×6.25.
1897.	Grams.	Per Ct.	Grams.	Grams	Grams.	Grams.	Grams.
May 18–19, 7 A. M.–7 A. M.,	1350	1.27	17.5	1.5	19.1	+ .1	+ .6
May 19–20, 7 A. M.–7 A. M.,	1109	1.48	16.6	1.5	19.1	+1.0	+ 6.2
May 20–21, 7 A. M.–7 A. M.,	1034	1.47	15.4	1.5	19.1	+2.2	+13.8
May 21–22, 7 A. M.–7 A. M.,	1305	1.25	16.5	1.5	19.1	+1.1	+ 6.9
Total, - - -	4798	—	66.0	6.0	76.4	+4.4	+27.5

* Including nitrogen in perspiration.

DIGESTION EXPERIMENT NO. 41.

Kind of food: Mixed diet. *Subject:* Laboratory janitor (E. O.). *Weight* (without clothes): At beginning, 66.8 kilos; at end, 66.7 kilos. *Duration:* Five days, with fifteen meals.

TABLE 38.

Lab. No. of Sample.	Food Materials.	Weight of Material.	Total Organic Matter.	Protein. N. × 6.25.	Fat.	Carbo-hydrates.	Ash.	Heats of Combustion. Determined.
		Grams	Grams	Grams	Grams	Grams	Grams	Cal.
2795	Beef, fried, - - -	850	274	217	57	—	11	1709
2796	Beef, dried, - - -	125	34	30	4	—	9	199
2798	Eggs, boiled, - - -	722	138	72	66	—	5	1028
2801	Butter, - - - -	75	65	1	64	—	3	595
2800	Milk, - - - -	2875	351	101	138	112	22	2133
2804	Bread, rye, - - -	750	420	63	4	353	12	1636
2786	Sugar, - - - -	225	225	—	—	225	—	892
2797	Beans, baked, - -	625	169	39	6	124	12	786
—	Pears, canned, - -	750	144	2	4	138	2	577
—	Alcohol, - - - -	348	592	—	—	592	—	2460
	Total, - - -	7345	2412	525	343	1544	76	12015
2809	Feces, - - - -	404	97	48	22	27	19	632
—	Am't (digested) available,	—	2315	477	321	1517	57	11383
			%	%	%	%	%	
—	Per cent. available, - -	—	96.0	90.9	93.6	98.3	75.0	—
—	Estimated heat of combustion of urine, - -	—	—	—	—	—	—	596
—	Energy of food oxidized in the body, - - -	—	—	—	—	—	—	10787
								%
—	Per cent. energy available,	—	—	—	—	—	—	89.8

Remarks.—This experiment, which represents the preliminary period of metabolism experiment No. 7, began with breakfast June 3, 1897, and continued five days. Alcohol was substituted for a portion of the carbohydrates and fats of an ordinary diet. During the five days of the experiment 363 grams of absolute alcohol was consumed, of which, according to the results obtained in the second period, 15 grams was eliminated from the body unchanged. As the potential energy of 1 gram of alcohol is approximately equivalent to that of 1.7 grams of carbohydrates the remaining 348 grams is assumed as corresponding to 348 x 1.7 or 592 grams of carbohydrates. The subject did but little work, remaining as quiet as was practicable. The following table shows the income and outgo of nitrogen. The urine for the first day was not collected, that for the second day appeared abnormal and was discarded.

Income and outgo of nitrogen in digestion experiment No. 41.

Period.	Weight of Urine.	Nitrogen in Urine.		Nitrogen in Feces.	Nitrogen in Food.	Gain + or Loss —	
						Nitrogen.	Protein. N.×6.25.
1897.	Grams.	PerCt.	Grams.	Grams	Grams.	Grams.	Grams.
June 5–6, 7 A. M.–7 A. M.,	1073	1.78	19.1	1.5	16.8	—3.8	—23.7
June 6–7, 7 A. M.–7 A. M.,	937	1.70	15.9	1.5	16.8	— .6	— 3.8
June 7–8, 7 A. M.–7 A. M.,	1845	1.00	18.5	1.5	16.8	—3.2	—20.0
Total, - - -	3855	4.48	53.5	4.5	50.4	—7.6	—47.5

DIGESTION EXPERIMENT NO. 42.

Kind of food: Mixed diet. *Subject:* Laboratory janitor (E. O.). *Weight* (without clothes): At beginning, 66.7 kilos; at end, 66.0 kilos. *Duration:* Four days, with twelve meals.

TABLE 39.

Lab. No. of Sample.	FOOD MATERIALS.	Weight of Material.	Total Organic Matter.	Protein. N. × 6.25.	Fat.	Carbo-hydrates.	Ash.	Heats of Combustion. Determined.
		Grams	Grams	Grams	Grams	Grams	Grams	Cal.
2795	Beef, fried, - - -	675	217	172	45	—	9	1357
2796	Beef, dried, - - -	100	27	24	3	—	7	160
2798	Eggs, boiled, - - -	564	107	56	51	—	4	803
2801	Butter, - - - -	60	53	1	52	—	2	476
2800	Milk, - - - -	2300	281	81	110	90	18	1707
2804	Bread, rye, - - -	600	336	50	4	282	10	1309
2786	Sugar, - - - -	180	180	—	—	180	—	713
2797	Beans, baked, - -	500	135	31	5	99	10	628
—	Pears, canned, - -	600	115	2	3	110	1	461
—	Alcohol, - - - -	278	473	—	—	473	—	1967
	Total, - - -	5857	1924	417	273	1234	61	9581
2810	Feces, - - - -	198	47	22	10	15	10	303
—	Am't (digested) available,	—	1877	395	263	1219	51	9278
			%	%	%	%	%	
—	Per cent. available, - -	—	97.6	94.7	96.3	98.8	83.6	—
—	Estimated heat of combustion of urine, - -	—	—	—	—	—	—	482
—	Energy of food oxidized in the body, - - -	—	—	—	—	—	—	8796
								%
—	Per cent. energy available,	—	—	—	—	—	—	91.8

Remarks.—This experiment began with breakfast June 8, 1897, and continued four days. It represents that period of metabolism experiment No. 7 which was passed in the respiration calorimeter. The subject entered the calorimeter the evening of June 6 and remained until 7 o'clock the morning of June 12. The diet included 290 grams of absolute alcohol, 12 grams of which were eliminated from the body unchanged during the four days of the experiment. The subject was very quiet while in the respiration chamber, moving around no more than was necessary. The diet was so small in amount and in bulk that, both in this and the first period, he experienced some hunger. The following table shows the income and outgo of nitrogen in this experiment:

Income and outgo of nitrogen in digestion experiment No. 42.

PERIOD.	Weight of Urine.	Nitrogen in Urine.*		Nitrogen in Feces.	Nitrogen in Food.	GAIN + OR LOSS —	
						Nitro-gen.	Protein. N.×6.25.
1897.	Grams.	PerCt.	Grams.	Grams	Grams.	Grams.	Grams.
June 7– 8, 7 A. M.–7 A. M.,	1457	1.34	19.6	.9	16.7	—3.8	—23.8
June 8– 9, 7 A. M.–7 A. M.,	2203	.81	17.8	.9	16.7	—2.0	—12.5
June 9–10, 7 A. M.–7 A. M.,	1499	1.07	16.2	.9	16.7	— .4	— 2.5
June 10–11, 7 A. M.–7 A. M.,	1378	1.26	17.3	.9	16.7	—1.5	— 9.4
Total, - - -	6537	—	70.9	3.6	66.8	—7.7	—48.2

* Including nitrogen in perspiration.

DIGESTION EXPERIMENT NO. 43.

Kind of food: Mixed diet. *Subject:* Laboratory janitor (E. O.). *Weight* (with clothes): At beginning, 72.1 kilos; at end, 71.6 kilos. *Duration:* Four days, with 12 meals.

TABLE 40.

Lab. No. of Sample.	FOOD MATERIALS.	Weight of Material.	Total Organic Matter.	Protein. N. × 6.25.	Fat.	Carbo-hydrates.	Ash.	Heats of Combustion. Determined.
		Grams	Grams	Grams	Grams	Grams	Grams	Cal.
2820	Beef, fried,	600	227	165	62	—	13	1488
2818	Eggs,	413	107	58	50	—	4	840
2827	Butter,	140	121	2	119	—	5	1088
2826	Milk,	3400	489	119	174	199	21	3068
2814	Bread, rye,	1310	726	131	5	670	22	3632
—	Sugar,	160	160	—	—	160	—	636
2816	Beans, baked,	500	138	34	2	98	11	620
2822	Apples,	800	114	2	4	108	2	468
	Total,	7323	2082	511	416	1233	78	11840
2824	Feces,	442	99	44	23	32	21	632
—	Am't (digested) available,	—	1983	467	393	1201	57	11208
			%	%	%	%	%	
—	Per cent. available,	—	95.3	91.4	94.5	97.4	73.1	—
—	Estimated heat of combustion of urine,	—	—	—	—	—	—	584
—	Energy of food oxidized in the body,	—	—	—	—	—	—	10624
								%
—	Per cent. energy available,	—	—	—	—	—	—	89.7

Remarks.—This experiment, which represents the preliminary period of metabolism experiment No. 8, began with breakfast November 8, 1897, and continued four days. The subject took but little active exercise during this period. The diet was slightly larger in amount than during the previous metabolism experiment in which it was found that the subject lost fat. The following table shows the income and outgo of nitrogen in this experiment:

Income and outgo of nitrogen in digestion experiment No. 43.

PERIOD.	Weight of Urine.	Nitrogen in Urine.		Nitrogen in Feces.	Nitrogen in Food.	GAIN + OR LOSS —	
						Nitrogen.	Protein. N.×6.25.
1897.	Grams.	PerCt.	Grams.	Grams	Grams.	Grams.	Grams.
Nov. 4–5, 7 A. M.–7 A. M.,	1640	.63	10.3	1.8	20.5	+ 8.4	+ 52.5
Nov. 5–6, 7 A. M.–7 A. M.,	1246	1.20	15.0	1.7	20.4	+ 3.7	+ 23.1
Nov. 6–7, 7 A. M.–7 A. M.,	1012	1.32	13.4	1.8	20.5	+ 5.3	+ 33.1
Nov. 7–8, 7 A. M.–7 A. M.,	1745	1.03	18.0	1.7	20.4	+ .7	+ 4.4
Total,	5643	—	56.7	7.0	81.8	+18.1	+113.1

DIGESTION EXPERIMENT NO. 44.

Kind of food: Mixed diet. *Subject:* Laboratory janitor (E. O.). *Weight* (without clothes): At beginning, 67.6 kilos, at end, 66.5 kilos. *Duration:* Four days, with 12 meals.

TABLE 41.

Lab. No. of Sample.	FOOD MATERIALS.	Weight of Material.	Total Organic Matter.	Protein. N. × 6.25.	Fat.	Carbo-hydrates.	Ash.	Heats of Combustion. Determined.
		Grams	Grams	Grams	Grams	Grams	Grams	Cal.
2821	Beef, fried, - - -	600	232	189	43	—	10	1448
2819	Eggs, - - - - -	380	88	47	41	—	4	680
2827	Butter, - - - - -	140	121	2	119	—	5	1088
2826	Milk, - - - - -	3400	486	116	173	197	21	3068
2815	Bread, rye, - - -	1300	795	129	1	665	22	3572
—	Sugar, - - - - -	160	160	—	—	160	—	636
2817	Beans, baked, - -	500	130	33	2	95	11	604
2823	Apples, - - - - -	800	120	2	4	114	2	492
	Total, - - -	7280	2132	518	383	1231	75	11588
2825	Feces, - - - - -	284	70	31	17	22	16	467
—	Am't (digested) available,	—	2062	487	366	1209	59	11121
			%	%	%	%	%	
—	Per cent. available, - -	—	96.7	94.0	95.6	98.2	78.7	—
—	Estimated heat of combustion of urine, - -	—	—	—	—	—	—	609
—	Energy of food oxidized in the body, - - -	—	—	—	—	—	—	10512
								%
—	Per cent. energy available,	—	—	—	—	—	—	90.7

Remarks.—This experiment began with breakfast November 12, 1897, and continued four days. It represents the second period of metabolism experiment No. 8, namely, that passed in the respiration calorimeter. The subject entered the calorimeter on the evening of November 11 and remained until 7 o'clock on the morning of November 16 when the experiment ended. As is the case in all these metabolism experiments one separation of the feces marks the end of the first and the beginning of the second period of the experiment. The following table shows the income and outgo of nitrogen:

Income and outgo of nitrogen in digestion experiment No. 44.

PERIOD.	Weight of Urine.	Nitrogen in Urine.		Nitrogen in Feces.	Nitrogen in Food.	GAIN + OR LOSS —	
						Nitrogen.	Protein. N. × 6.25.
1897.	Grams.	Per Ct.	Grams.	Grams	Grams.	Grams.	Grams.
Nov. 12–13, 7 A. M.–7 A. M.,	3208	.65	20.9	1.3	20.8	—1.4	—8.8
Nov. 13–14, 7 A. M.–7 A. M.,	2268	.83	18.9	1.2	20.7	+ .6	+3.8
Nov. 14–15, 7 A. M.–7 A. M.,	1958	.97	19.0	1.3	20.8	+ .5	+3.1
Nov. 15–16, 7 A. M.–7 A. M.,	1839	1.05	19.2	1.2	20.7	+ .3	+1.9
Total, - - -	9273	—	78.0	5.0	83.0	.0	0.0

The figures for "estimated heat of combustion" of urine in the above tables demand a word of explanation. In experiments 38, 40, 42, and 44 they are based upon direct determination of the nitrogen and the heat of combustion of the water-free substance of the urine. In the others, 37, 39, 41, and 43, they are computed by assuming that the heat of combustion of the water-free substance of the urine will be 1.25 calories for each gram of digested (available) protein. This factor is the average found in a number of experiments in this laboratory, in which the heat of combustion of the water-free substance of the urine was determined..

In the following table the results of the above experiments, Nos. 37–44, together with eight others, Nos. 45–52, are summarized.

TABLE 42.

Total amounts of nutrients and energy in the food consumed per day in the above experiments, and the proportion digested (available).

No. of Expt.	Metabolism Expt. No.	DESCRIPTION.	Protein.		Fat.		Carbo-hydrates.		Energy.	
		First or Preliminary Period of Metabolism Experiments.	Gm	%	Gm	%	Gm	%	Cal.	%
37	5	Mixed diet, ordinary work, -	121	92.7	96	94.0	275	98.0	2675	89.9
39	6	Mixed diet, hard work, - -	119	90.1	154	95.3	378	97.6	3685	91.2
41	7	Mixed diet, with alcohol, rest, -	105	90.9	69	93.6	309	98.3	2405	89.8
43	8	Mixed diet, light work, - -	128	91.4	104	94.5	308	97.4	2960	89.7
45	9	Mixed diet, light work, - -	118	90.9	69	92.1	340	95.8	2705	88.4
47	10	Mixed diet, with alcohol, rest, -	122	94.9	31	92.1	419	98.6	2690	91.3
49	11	Mixed diet, hard work, - -	125	90.6	129	93.2	484	97.8	3860	91.2
51	12	Mixed diet, with alcohol, hard work	123	95.3	163	94.3	422	96.4	3930	91.2
		Average eight periods, - -	**120**	**92.1**	**102**	**93.6**	**367**	**97.5**	**3115**	**90.3**
		Second Period of Metabolism Experiments. Subject in Respiration Calorimeter.								
38	5	Mixed diet, rest, - - -	119	91.4	95	93.9	276	97.6	2655	90.0
40	6	Mixed diet, hard work, - -	119	92.2	153	96.9	378	98.3	3675	92.6
42	7	Mixed diet, with alcohol, rest, -	104	94.7	68	96.3	309	98.8	2395	91.8
44	8	Mixed diet, rest, - - -	129	94.0	96	95.6	308	98.2	2895	90.7
46	9	Mixed diet, rest, - - -	118	93.4	69	93.9	340	96.5	2705	89.5
48	10	Mixed diet, with alcohol, rest, -	124	92.9	31	88.1	418	97.8	2700	90.2
50	11	Mixed diet, hard work, - -	125	88.8	129	93.0	485	97.5	3860	90.9
52	12	Mixed diet, with alcohol, hard w'k,	121	93.6	159	95.9	414	98.7	3870	93.1
		Average eight periods, - -	**120**	**92.6**	**100**	**94.2**	**366**	**97.9**	**3095**	**91.1**

SOME PRACTICAL APPLICATIONS OF RESULTS OF FOOD INVESTIGATIONS.

BY W. O. ATWATER AND A. P. BRYANT.

The Reports and Bulletins of this Station for several years past have given accounts of various investigations bearing upon the food and nutrition of man. Some of these have shown the composition of food materials, that is to say, the amounts of nutritive ingredients which they contain. Others have had to do with the digestibility of different kinds of food, or in other words, the amounts of the different nutritive ingredients which can be actually utilized by people in good health and with normal digestion. In still others, the kinds and amounts of food consumed by people of different classes have been studied. The results of these investigations are given in the studies of dietaries. Finally a series of experiments are being made with men in the respiration calorimeter, the practical object of this inquiry being to get more light upon the ways in which food is used in the body and the kinds and amounts that are best fitted for the various purposes of nutrition. The work which is thus being done in connection with the Storrs Station forms a part of a general inquiry which has been going on for several years past in different regions in the United States, and it is in line with inquiries upon these subjects that have been and are now being carried out in constantly increasing number in other parts of the world. As the result of this inquiry a large amount of information is accumulating. The purpose of the present article is to indicate some of the ways in which part of this information, namely, that which has to do with the kinds and amounts of nutrients required by the body for nourishment and contained in ordinary food materials, may be practically utilized by ordinary people.

As this report will come into the hands of many who are not versed in physiological chemistry, the following brief explanations are made:

Ordinary food materials, such as meat, fish, eggs, potatoes, wheat, etc., consist of—

Refuse.—As the bones of meat and fish, shells of shellfish, skins of potatoes, bran of wheat, etc.

Edible portion.—As the flesh of meat and fish, the white and yolk of eggs, wheat flour, etc. The edible portion consists of *water* and *nutritive ingredients* or *nutrients*. The principal kinds of nutritive ingredients are *protein*, *fats*, *carbohydrates*, and *mineral matters*.

The water, refuse, and salt of salted meat and fish are called non-nutrients. In comparing the values of different food materials for nourishment they are left out of account.

Food supplies the wants of the body in several ways. It either—

Is used to form the tissues and fluids of the body;

Is used to repair the wastes of tissues;

Is stored in the body for future consumption;

Is consumed as fuel, its potential energy being transformed into heat or muscular energy, or other forms of energy required by the body; or,

In being consumed protects tissues or other food from consumption.

The fuel value of food.—Heat and muscular power are forms of force or energy. The energy is developed as the food is consumed in the body. The unit commonly used in this measurement is the calorie, the amount of heat which would raise the temperature of a pound of water about 4° F.

The following general estimate has been made for the average amount of energy available in 1 pound of each of the classes of nutrients:

	Calories.
In 1 pound of protein, - - - - - - - -	1,860
In 1 pound of fats, - - - - - - - - -	4,220
In 1 pound of carbohydrates, - - - - - - -	1,860

In other words, when we compare the nutrients in respect to their fuel values, their capacities for yielding heat and mechanical power, a pound of protein of lean meat or albumen of egg is just about equivalent to a pound of sugar or starch, and a little over two pounds of either would be required to equal a pound of the fat of meat or butter or the body fat.

When an intelligent and economical housewife goes to the market to make her purchases, she is thinking of meat and flour and potatoes; what they cost, and how they will be relished. But in fact, though she does not realize it, she is buying certain nutritive substances in the food—tissue formers and fuel ingredients, which she and her husband need to repair the wastes of their bodies and to give them strength for their daily toil, and which their children must have for healthy growth and work and play. Her real problem, though she does not understand it, is to get the most and the best nutriment for her money. The members of the family need, as essential for the day's diet, certain amounts of protein to make blood and muscle, bone and brain, and corresponding quantities of fat, starch, sugar, and the like, to be consumed in their bodies, and thus to serve as fuel to keep them warm and to

give them strength for work—a larger amount for the father, with his active muscular labor; somewhat less for the mother, with her smaller body and lighter work; and quantities for the children according to age, growth, and occupation. Of course they need other substances, like mineral salts, which are contained in the food, and the water of both food and drink, and they want and will have things like salt and spice and tea and coffee, which gratify the palate and are more or less useful for nourishment.

If the family be that of a mechanic or day-laborer in a village or city in Connecticut with an annual income of between $800 and $400 for instance, half of this sum will generally be spent for food. Due regard for health, strength, and purse requires that food shall supply enough protein to build tissue and enough fats and carbohydrates for fuel, and that it shall not be needlessly expensive. The protein can be had in the lean of meat and fish, in eggs, in the casein (curd) of milk, in the gluten of flour, and in substances more or less like gluten in various forms of meal, potatoes, beans, peas, and the like. Fats are supplied in the fat of meat and fish, in lard, in the fat of milk, or in the butter made from it; it is also furnished, though in small amounts, in the oil of wheat, corn, potatoes, and other vegetable foods. Carbohydrates occur in great abundance in vegetable materials, as in the starch of grains and potatoes, and in sugar. The fats, sugars, and starches all serve for fuel, and we may measure their quantity by their fuel value, expressing this in heat units, or calories. In the food this woman buys, then, she has to deal with protein, or tissue formers, and with fuel values.

If her husband is engaged at moderately hard muscular work, like that of a carpenter or mason or active day laborer, he should have in his day's food say 0.28 pound of protein and enough carbohydrates and fats so that the fuel value of the whole will be about 3,500 calories. The wife, if busy at work with her hands about the house or otherwise, will need perhaps eight-tenths as much. If the children are two boys of 13 and 8 and two girls of 10 and 5 years of age, they will need enough to make the wants of the whole family equivalent, let us say, to four men at moderately hard work. This would require 1.12 pounds of protein, and a fuel value of 14,000 calories. It

could be supplied by various food mixtures—some dearer and some cheaper. If the costlier meats, oysters, or eggs at high prices are used, the diet will be an expensive one, but if the animal food is used in the forms of the less costly meats, in milk and cheese in not too large quantities, and if the bulk of the diet consists of such wholesome vegetable foods as wheat flour, corn meal, oatmeal, peas, beans, and potatoes when the last are not too dear, the cost will be very much less.

THE NUTRITIVE INGREDIENTS OF FOOD.

In the report of this Station for 1896, may be found a table giving the composition of the more common food materials. Some specimens of food mixtures, with amounts of ingredients and costs, are given in the daily menus beyond.

Our common food materials differ greatly in the amounts of nutrients they contain. Of the whole weight of an average piece of beefsteak, round, a little less than one-third would be actual nutritive material. In smoked ham the proportion of nutritive ingredients is larger, nearly one-half the whole weight. In milk the proportion is a little over one-eighth, in potatoes less than one-fifth, while in wheat flour seven-eighths of the whole weight consists of actual nutrients.

The different food materials differ likewise in the kinds of nutritive ingredients. Thus in butter, salt pork, and wheat flour seven-eighths of the weight is nutritive material. In the butter and fat pork this material consists almost entirely of fatty or oily substances, while the wheat flour has extremely little fat or oil. Its chief ingredient is starch, although it contains considerable quantities of protein in the albuminoid compounds of the gluten. A pound of potatoes as ordinarily cooked and eaten would furnish a little over one-sixth of a pound of actual nutrients, which is a little more than the amount in a pound of salt codfish. But the nutritive material of the salt codfish would be mainly protein, while in the potatoes it would be chiefly starch, and neither would contain any considerable amount of fat. In milk and oysters the nutritive ingredients make about one-eighth of the total weight, and the proportions of protein, fats and carbohydrates are so nearly alike in the two that both might be grouped together as having similar nutritive value. But the flour and butter, although they contain the same amount of nutritive ingredients, could

not be classed in the same group, because the nutrients are so different in kind. Leaving out of account the flavor, and considering simply the value for nourishing the body, butter, lard, salt pork, and olive oil would be very similar. The same would be true of wheat flour, corn meal, and rice, all of which contain nearly the same proportions of protein, fats and carbohydrates, although the protein in wheat flour is slightly larger in amount than in the other materials mentioned.

In what has been said no account has been taken of the digestibility or availability of the food. By digestibility, as the word is ordinarily used, two things are really meant. One is the proportion which can be digested and thus made available to the body. For this the term availability would be better, as stated on page 156 above. The other has to do with the fitness of the food for the use of the particular individual who eats it. For most people milk is a very wholesome article of diet. Some cannot take it without discomfort. It does not "agree" with them. Eggs are likewise a very nutritious article of food, but they disagree with many people. In common parlance foods which "agree" are called digestible and those which disagree are often spoken of as undigestible. This difference is a matter of individuality and cannot be taken into account in the present discussion. The proportions of the different food materials that are actually digested or available differ more or less in different food materials.*

The proportions of nutrients in materials commonly used as food have been given in previous Reports of the Station. In the Report for 1896 may be found a table showing the proportion of digestible or available nutrients in a considerable number of the more common food materials. It is hoped that a future Report may treat more fully of the digestibility and availability of food. It will suffice to say here that our ordinary food materials differ much less in the availability of their nutrients than is commonly supposed.

GROUPING OF FOOD MATERIALS BY NUTRITIVE VALUES.

For practical purposes it will be convenient to classify the more common food materials in groups according to their nutritive values. Such a classification is attempted in table 43 beyond. The grouping is made with reference to the menus beyond. In each group the different members have very nearly the

* See statements regarding this subject in previous article.

same nutritive value, that is to say, they furnish nearly the same amounts of protein and energy. Generally speaking the amount of each material in each group is taken as one pound. In some cases, however, the composition of the material is such as to make it necessary to use more or less than one pound in the grouping. For example, one pound of round steak, one pound of shoulder clod, one and a half pounds of veal neck, and five and a half pounds of skimmed milk furnish nearly the same amounts of protein and of energy, and may be considered as of nearly the same nutritive value. In table 43 a number of food materials are grouped in the manner thus described. The first column shows the amount of each material taken to make it equivalent to the others of the group as a source of nutriment. The amounts of protein and energy in each material are given, thus showing the minor differences in nutritive value.

Some of the most important food materials which might be grouped together are here separated, because they are so important that even minor differences in composition need to be taken into account. Wheat flour and corn meal, for example, have nearly the same amounts of total nutrients and energy, but the flour has rather more protein and it makes up so large a part of the ordinary diet that the same weight of corn meal with five-sixths as much protein could hardly take its place. The food materials which do not readily admit of grouping with others, are given separately at the end of the table.

The prices per pound in table 43 are the mean of those actually charged in eighteen different grocery stores and meat and fish markets in different places in Connecticut in 1897. These prices are used in estimating the costs of the menus beyond. The estimate of 4 cents per pound for home-made bread allows about one-half for flour, shortening, yeast, etc., and one-half for fuel and labor. Bakers' bread was found to average not far from 6 cents per pound where inquiries were made.

The purpose of the grouping of food materials in the table is not only to show what ones have nearly the same proportions of actual nutriments, but also to bring out the contrasts between those with different values. In making up a daily menu the members of the same group or those of different groups not differing greatly in protein and energy can be interchanged without greatly changing the nutritive value of the whole menu.

Table 43.

Food materials arranged in groups, the different members of which furnish nearly the same amounts of protein and energy.

Amount.	Groups.	Price per Lb.	Protein.	Fuel Value.
Lbs	MEATS.	Cts.	Lbs.	Cal.
	I.			
1	Beef, round,	14	.190	895
1	Beef, clod,	12	.196	840
¾	Beef, canned corned,	12	.197	970
1	Veal, cutlet,	23	.201	690
1½	Veal, neck,	8	.208	680
5½	(Milk, skim'd, 5½ pts.),	1½	.187	905
	II.			
1	Beef, chuck,	10	.166	735
1	Beef, shoulder,	12	.164	720
1	Veal, shoulder,	12	.154	750
1	Veal, loin,	18	.167	675
1	Mutton, leg,	14	.151	900
1	Chicken,	16	.142	750
1¼	(Eggs, 10),*	16	.146	790
	III.			
1	Beef, neck,	7	.145	770
¾	Beef, rib roll,	16	.145	800
⅞	Beef, loin,	18	.122	925
1	Mutton, shoulder,	12	.137	910
1	Mutton, neck,	6	.123	985
½	(Cheese),	16	.130	970
	IV.			
1	Beef, ribs,	16	.139	1155
1	Beef, rump,	12	.136	1120
1	Beef, brisket,	6	.120	1165
1	Beef, corned rump,	12	.143	1195
1	Beef, corned brisket,	8	.144	1085
⅝	(Beans, dried),	4	.140	1000
	V.			
1	Beef, plate,	6	.138	1285
1	Mutton, forequarter,	8	.123	1265
1	Mutton, chuck,	12	.119	1350
1	Pork, smok'd shoulder,	12	.130	1365
1	Pork, loin (chops),	10	.146	1350
4	(Milk, 2 qts.),	3	.132	1400
	VI.			
1	Pork, smoked ham,	20	.136	1665
1	Beef, navel,	6	.138	1620
1⅛	Beef, corned flank,	8	.145	1655

Amount.	Groups.	Price per Lb.	Protein.	Fuel Value.
Lbs	FISH.	Cts.	Lbs.	Cal.
	VII.			
1	Bluefish,	12	.100	210
1	Codfish,	12	.111	215
1	Pickerel,	—	.107	210
1	Red snapper,	—	.106	210
1	Trout, brook,	—	.099	230
1¼	Haddock,	8	.105	205
1½	Perch, yellow,	6	.096	200
⅝	Scallops,	25	.092	215
9/16	Salt cod,	9	.108	210
	VIII.			
1	Herring, smoked,	5	.112	375
1	Mackerel, fresh,	12	.116	365
1	Shad,	12	.094	380
1½	Oysters,	18	.090	345
	IX.			
1	Perch, white,	—	.073	200
½	Halibut,	18	.076	235
½	Scallops,	25	.074	170
1¼	Oysters, "solids,"	18	.075	290
¾	Clams, "solids,"	15	.079	215
	VEGETABLES.			
	X.			
1	String beans,	3	.023	220
1	Beets,	1½	.016	225
1	Onions,	3	.015	215
1	Parsnips,	1½	.013	240
2	Squash,	2½	.014	210
2	Turnips,	1	.018	250
2	Tomatoes, fresh,	3	.018	210
4	Rhubarb,	—	.016	260
3/16	(Bread, home made),	4	.018	220
	XI.			
1	Cabbage,	2½	.014	125
1	Cauliflower,	—	.018	140
2	Radish,	12	.018	190
2	Celery,	5	.020	160
2	Cucumber,	1	.016	160
2	Lettuce,	5	.020	150
1/16	(Cheese),	16	.017	125

* One dozen eggs are assumed to weigh on the average about 1½ lbs.

TABLE 43.—*(Continued.)*

Amount.	GROUPS.	Price per Lb.	Protein.	Fuel Value.
Lbs	VEGETABLES. *(Continued.)*	Cts.	Lbs.	Cal.
	XII.			
1	Tomatoes,	3	.009	105
1	Squash,	2½	.007	105
1	Turnips,	1	.009	125
½	String beans,	3	.011	110
½	Beets,	1½	.008	110
½	Onions,	3	.007	105
½	Parsnips,	1½	.006	120
½	Potatoes,	2	.006	110
⅛	(Bread, home made),	4	.012	140
	XIII.			
1	Radishes,	12	.009	95
1	Celery,	5	.010	80
1	Cucumbers,	1	.008	80
1	Lettuce,	5	.010	75
½	Spinach,	—	.011	55
½	Cabbage,	2½	.007	65
½	Cauliflower,	—	.009	70
	FRUITS (OR SUBSTITUTES).			
	XIV.			
1	Bananas,	7	.009	325
1	Blackberries,	4	.010	350
1	Cherries,	6	.011	360
1	Grapes,	3	.010	335
1	Plums,	6	.009	370
1½	Raspberries,	6	.015	350
1½	Peaches,	4	.010	330
¼	Figs, dried,	11	.013	350
2	Oranges,	7	.012	300
2	Strawberries,	6	.020	370
4	Muskmelons,	5	.012	360
5	Watermelons,	—	.010	300
¼	Apricots, dried,	10	.012	320
⅛	(Wheat, breakf't food),	7	.016	320
1	(Potatoes),	2	.017	310
	XV.			
1	Pears,	—	.006	310
1	Huckleberries,	4	.007	390
1½	Apples,	1½	.005	345
1½	Cranberries,	4	.006	320
1½	Pineapple,	—	.006	300
⅛	Prunes, dried,	10	.006	395
¼	Raisins,	10	.006	360
¼	Dates,	8	.006	410
—	1 oz. wheat breakf't food, 2 oz. sugar,	—	.008	390
—	¾ oz. rolled oats, 2 oz. sugar,	—	.007	320

Amount.	GROUPS.	Price per Lb.	Protein.	Fuel Value.
Lbs	MISCELLANEOUS.	Cts.	Lbs.	Cal.
	XVI.			
1	Biscuit,	4	.084	1430
1	Rolls,	4	.102	1530
1	Macaroni,	12	.118	1645
1	Wheat flour,	3	.112	1655
1¼	Johnny cake,	4	.106	1440
1½	Bread,	4	.117	1520
	NOT GROUPED.			
1	Dried Beef,	25	.264	780
1	Butter,	28	.010	3605
1	Salt pork,	10	.019	3670
1	Lard,	9	—	4220
1	Wheat flour,	3	.112	1655
1	Corn meal,	2½	.093	1670
1	Barley, pearled,	—	.093	1660
1	Buckwheat flour,	3	.057	1610
1	Buckwheat flour, prep.,	6	.082	1570
1	Rice,	8	.078	1635
1	Rye flour,	4	.068	1630
1	Oatmeal, "rolled oats,"	4	.168	1850
1	Wheat preparati'ns, "Breakfast foods," "Breakfast cereals," etc.,	7½	.124	1700
1	Crackers,	8	.105	2000
1	Beans, dried,	4	.225	1595
1	Peas, dried,	4	.246	1665
1	Potatoes,	2	.017	310
1	Sweet potatoes,	2	.014	460
1	Sugar,	6	—	1860
1	Tapioca,	6	.004	1650
1	Cornstarch,	8	—	1745
1	Cocoa,	—	.216	2320
1	Chocolate,	—	.129	2860
1	Peanuts,	—	.195	1935
1	Chestnuts, fresh,	—	.057	1115

DIETARY STANDARDS.

In order that the food may be adapted to the needs of the consumer it should have the protein and fuel ingredients (fats and carbohydrates) in the proper proportions. It has been assumed from the most accurate data available that an average laboring man, *i. e.*, a man doing an ordinary amount of manual labor, requires in his daily food about .28 of a pound of protein and in addition enough fats and carbohydrates to make the fuel value 3,500 calories. Men in professional life with less muscular work generally need less food. Standards for men of this class call for .22 to .25 of a pound of protein and from 2,700 to 3,000 calories of energy. A man at severe work on the other hand would need large amounts of nutrients, .33 lb. of protein and 4,500 calories of energy for instance.

Various combinations of foods for daily dietaries according to either of the standards above quoted may be made by calculations based on the chemical composition of various foods. A few such calculations are here given in the form of daily menus in which the actual amounts of different food materials required by a family equivalent to four men at ordinary exercise are given. Such a family might, for example, consist of a man and his wife with three children under 10 years of age and one female servant, or of a man and his wife with two children between 10 and 16 years of age and one servant. The equivalent of any family in terms of one adult man at moderate work, one day, can be easily calculated by the use of the following factors which are based in part upon experimental data and in part upon arbitrary assumption. While these factors do not represent the proportional amount consumed by every child of a given age they are probably on the whole as nearly accurate as can be obtained without considerable more experimental data. The gradations here used are as follows:

A man at hard muscular work,	1.2
A man at moderate muscular work,	1.0
A man at light muscular work,	.8
A woman at moderate muscular work,	.8
A woman at light muscular work,	.7
A boy 14–16 years old with moderate exercise,	.8
A girl 14–16 years old with moderate exercise,	.7
A child 10–13 years old with moderate exercise,	.6
A child 6–9 years old with moderate exercise,	.5
A child 3–5 years old with moderate exercise,	.4
A child under 2 years old with moderate exercise,	.3

A family might, for example, consist of a mechanic and wife with four children, two girls of 12 and 6 and two boys of 10 and 8 years respectively. Here it would be assumed that the man would be engaged at moderately hard manual work. According to the above factors this family would be equal, in food consumption, to $1.0+.8+.6+.6+.5+.5=4$ men at moderate muscular exercise. In the same way, a day laborer's family, consisting of a father and mother with three children under 7 years of age would be equivalent to $1.0+.8+.5+.4+.3$, or 3 men with moderate muscular exercise, and would require three-fourths the quantities indicated in the following menus.

DAILY MENUS.

The following menus attempt to give as nearly as possible such range of food materials and variety of combination as might be found in the average household of people in well-to-do circumstances. The quantities of the different foods used per meal will not, it is believed, be found out of proportion to each other, though of course they will not suit every family. The weights of all materials, oatmeal, and other cereals, meat, vegetables, etc., are for these substances as purchased.

The calculations of the quantities of nutrients contained in the different foods are based upon the average percentage composition of these materials. Inasmuch as the fats and carbohydrates are used mainly as fuel in the body they are not shown in the menus, only the quantity of protein and the fuel value of the food being taken into account.

The cost.—The prices per pound used in estimating the cost of the menus were taken as the mean of the prices charged by a number of retailers in Connecticut cities. While they represent average rates it is altogether probable that the ordinary family buys some materials more cheaply and pays more for others than these figures indicate. The cost must of necessity be a more or less varying quantity, depending upon the quality of the materials, the season of the year, the locality, the place itself, whether large or small, city or country, etc. The cost to the farmer of milk, vegetables, and fruits would be much less than the prices indicated.* The table on pages 174 and 175

* See note on page 188.

above gives the prices of the principal food materials used in the menus.

In the receipts for dishes prepared at home only the proportions of the different nutritive ingredients are indicated. Condiments, flavorings and other accessories which have little or no value as food are left out of account in the estimates of nutrients. The values given under the head "tea" or "coffee" are obtained by calculating the actual cost and nutrients of the ingredients entering into the coffee. It is calculated that the cost of the coffee, milk and sugar for one cup of coffee or tea will be not far from one cent, and the protein and energy furnished by the milk and sugar not far from .008 pound and 250 calories respectively. The coffee or tea infusion itself contains practically no nutrients.

In table 43 above a number of common food materials are arranged in groups. One purpose of putting the different articles of similar nutritive value into the same group, is to show how they may be interchanged in making up the menus. That is to say, any one of the materials in either menu may be taken out and another of the same group put in its place without changing the nutritive value of the whole. The change thus made may increase or diminish the cost of the food. Thus, for dinner in menu No. 1, 2 pounds 3 ounces of porterhouse steak (beef loin) costing, at 18 to 25 cents a pound, about 50 cents, might be substituted for the 2½ pounds of beef neck, which, at 7 cents a pound, would cost but 17½ cents. This change in the menu would, perhaps, give a more palatable meal, but at an increased cost of 33 cents, and without essential change of nutritive value. In menu No. 6 the 2½ pounds of beef rib costing, at 16 cents a pound, 40 cents, could be replaced by the same amount of boiled beef brisket costing, at 6 cents a pound, 15 cents. This would make a saving of 25 cents without loss of nutritive value. Or, in this same menu, 1 pound 9 ounces (about 1½ pints) of dried beans, costing not far from 6 cents, might be used in the place of the 2½ pounds of beef rib, thus reducing the cost 34 cents.

In like manner, in menu No. 4, instead of 1 pound of bananas (four) for breakfast, costing 7 cents, there might be substituted 1 pound of blackberries (1 pint), costing 4 cents, 2 pounds of oranges (4 large or 8 small ones), costing 14 cents,

or 4 pounds of muskmelon costing 15 or 20 cents. Just about the same amount of nutriment as would be supplied by either of these fruits would be furnished in 2 ounces of breakfast cereals costing about 1 cent, or in 2 ounces of corn meal or wheat flour costing from ¼ to ½ of a cent.

The question naturally arises, Will the nutrients in the beans be really worth as much as the same amount of nutrients in the meat, and will not the fruit have some value that does not belong to the breakfast foods or the flour?

The meats are very little more digestible than the beans, but the difference is very small. The meats also have very small amounts of materials, so-called extractives, which are highly prized for their flavor, and which are not contained in the beans. These extractives are the substances dissolved in the water in the preparation of beef tea and meat extracts. For invalids, and sometimes for people in good health, they are useful, but their use is medicinal, they have no value as nutriment. Ordinarily they are not at all essential.

The case is similar with fruits, as compared with the breakfast foods, or flour. We prize the fruits for their flavor, which is agreeable to the taste. Sometimes the vegetable acids they contain may have a medicinal value, and they may at times serve as an aid to digestion, and hence be useful to people with impaired digestive organs. But, for most people, and at most times, they would be no more useful, outside of their agreeableness to the palate, than the flour or meal, or the prepared breakfast foods.

In cooking it is understood that flour, sugar, butter, milk, etc., are measured rather than weighed. It is a very difficult matter to reduce "teaspoonfuls" and "tablespoonfuls" of materials to definite weights, and a "cupful" is likewise a very indefinite measure. In general the following averages have been taken for the weight of different measures of different foods:

One cupful = one-half pint,	= One-half pound of rice, corn starch, sugar, milk, syrup, butter.
	= Six ounces of hominy, corn meal, buckwheat.
	= One-fourth pound of flour, wheat breakfast foods, cerealine, oatmeal.

One tablespoonful	Flour, cereals, etc., = about one-half ounce.
	Corn meal = about three-fourth ounce.
	Butter, starch, rice, sugar, etc., ≐ about one ounce.

The weights of a cupful of the different foods may be considered as fairly accurate, but the estimated weight of one tablespoonful of different materials is one of the crudest makeshifts, depending upon the spoon, and, especially, upon what the person considers a spoonful.

Menu No. 1.—For one day. For family equivalent in demand for food to four men with moderate muscular work.

Food Materials.	Weight.	Cost.	Protein.	Fuel Value.
Breakfast.	Lbs. Oz.	Cents.	Lbs.	Calories.
Rolled oats,	– 6	2.4	.063	695
Milk,	– 6	1.1	.012	120
Sugar,	– 2	.8	—	235
Pork chops, or equivalent from group 5,	1 8	15.0	.219	2025
Bread, or equivalent from groups 12 or 16,	– 12	3.0	.071	910
Butter,	– 2	3.5	.001	440
Coffee,	– –	4.0	.008	250
Total,	– –	29.8	.374	4675
Dinner.				
Beef stew, neck, or equivalent from group 3,	2 8	17.5	.363	1925
Potatoes,	2 –	4.0	.034	620
Turnip, or equivalent from group 12,	1 8	1.5	.014	190
Bread,	– 12	3.0	.071	910
Butter,	– 2	3.5	.001	440
Cornstarch pudding (1 quart milk, 2 eggs, 4 oz. sugar, 3 oz. cornstarch),	2 11	13.0	.095	1600
Total,	– –	42.5	.578	5685
Supper or Lunch.				
Fried potatoes,	1 8	3.0	.026	490
Bread, or equivalent from group 16,	– 12	3.0	.071	910
Butter,	– 2	3.5	.001	440
Prunes,	1 –	10.0	.018	1190
Sugar,	– 4	1.5	—	465
Tea,	– –	4.0	.008	250
Total,	– –	25.0	.124	3745
Total per day,	– –	97.3	1.076	14105
Total for one man,	– –	24½	.27	3525

Menu No. 2. For one day. For family equivalent in demand for food to four men with moderate muscular work.

FOOD MATERIALS.	WEIGHT.		COST.	PROTEIN.	FUEL VALUE.
Breakfast.	Lbs.	Oz.	Cents.	Lbs.	Calories.
Muskmelon, or equivalent from group 14,	4	–	20.0	.012	360
Wheatlet,	–	4	1.5	.030	425
Milk,	–	6	1.1	.012	120
Sugar,	–	2	.8	—	235
Scrambled eggs (8),	1	–	16.0	.117	630
Bread, or equivalent from groups 12 or 16,	–	12	3.0	.071	910
Butter,	–	4	7.0	.002	880
Coffee,	–	–	4.0	.008	250
Total,	–	–	53.4	.252	3810
Dinner.					
Bluefish, or equivalent from group 7,	2	–	24.0	.200	420
Mashed potato,	2	–	4.0	.034	620
Dried lima beans, creamed (1 lb. lima beans, ½ pint milk, 1 oz. flour, 1 tablespoonful butter),	1	10	8.5	.267	2115
Radish, or equivalent from group 13,	–	8	6.0	.005	50
Bread,	–	12	3.0	.071	910
Butter,	–	2	3.5	.001	440
Cornstarch pudding (1 quart milk, 2 eggs, 4 oz. sugar, 3 oz. cornstarch),	2	11	13.0	.095	1600
Total,	–	–	62.0	.673	6155
Supper or Lunch.					
Creamed potatoes (1 pint potatoes, ½ pint milk, 1 oz. butter),	1	9	5.3	.033	690
Bread, or equivalent from group 16,	1	–	4.0	.094	1215
Butter,	–	4	7.0	.002	880
Pineapple, or equivalent from group 15,	1	–	6.0	.004	200
Sugar,	–	6	2.3	—	700
Cheese, or equivalent from group 3,	–	4	4.0	.065	485
Total,	–	–	28.6	.198	4170
Total per day,	–	–	144.0	1.123	14135
Total for one man,	–	–	36	.28	3535

As stated above, the weights of meats and vegetables given in the menus are for these articles as found in the market. The meats will include, as a rule, more or less bone, and the vegetables, considerable skin and other parts, which are inedible and are rejected. In estimating the nutrients allowance is made for what has been found to be the average proportion of bone in different cuts of meats. In vegetables it is assumed that from one-fifth to one-sixth will be rejected in preparing these for the table. The weights of the "breakfast" cereals are for those in the dry condition before cooking.

Menu No. 3.—For one day. For family equivalent in demand for food to four men with moderate muscular work.

Food Materials.	Weight.		Cost.	Protein.	Fuel Value.
	Lbs.	Oz.	Cents.	Lbs.	Calories.
Breakfast.					
Grapes, or equivalent from group 14, -	1	–	3.0	.010	335
Buckwheat cakes (½ lb. flour, ½ lb. buckwheat flour, 2 oz. sugar), -	1	2	4.1	.084	1860
Syrup, - - - - - - -	–	4	2.3	—	330
Pork sausage, - - - - - -	1	–	10.0	.130	2145
Coffee, - - - - - - -	–	–	4.0	.008	250
Total, - - - - - -	–	–	23.4	.232	4920
Dinner.					
Cod steaks, or equivalent from group 7,	2	–	24.0	.340	670
Baked potatoes, - - - - - -	2	–	4.0	.034	620
Creamed lima beans (½ pint milk, ½ oz. flour, 1 oz. butter, 1 lb. dried limas), - - - - - - -	1	9½	8.4	.232	2055
Pineapple cream (1 lb. pineapple, ½ oz. gelatine, 2 oz. sugar, ½ pint whipped cream), - - - - - - -	1	10½	17.9	.045	940
Total, - - - - - -	–	–	54.3	.651	4285
Supper or Lunch.					
Scalloped oysters (1 quart oysters, ¼ lb. crackers, 2 oz. butter, ¼ pint milk), - - - - - - -	2	10	41.3	.154	1470
French fried potatoes, - - -	1	–	2.0	.017	310
Lard, - - - - - - - -	–	2	1.1	—	530
Bread, or equivalent from group 16, -	–	8	2.0	.047	610
Butter, - - - - - - -	–	2	3.5	.001	440
Peaches, or equivalent from group 14,	1	–	4.0	.006	310
Sugar, - - - - - - -	–	4	1.5	—	465
Tea, - - - - - - - -	–	–	4.0	.008	250
Total, - - - - - -	–	–	59.4	.233	4385
Total per day, - - - - -	–	–	137.1	1.116	13590
Total for one man, - - - -	–	–	34½	.28	3395

Menu No. 4.—For one day. For family equivalent in demand for food to four men with moderate muscular work.

FOOD MATERIALS.	WEIGHT.		COST.	PROTEIN.	FUEL VALUE.
Breakfast.	Lbs.	Oz.	Cents.	Lbs.	Calories.
Bananas, or equivalent from group 14,	1	–	7.0	.009	325
Rolled oats, - - - - - -	–	4	1.6	.042	465
Milk, - - - - - - -	–	6	1.1	.012	120
Sugar, - - - - - - -	–	2	.8	—	235
Creamed dried beef (12 oz. dried beef, ½ pint milk, 1 tablespoonful butter),	1	5	22.0	.208	885
Potatoes, French fried, - - -	1	–	2.0	.017	310
Lard (taken up in frying), - -	–	2	1.1	—	530
Bread, or equivalent from groups 12 or 16,	–	12	3.0	.071	910
Butter, - - - - - - -	–	3	5.3	.001	660
Coffee, - - - - - - -	–	–	4.0	.008	250
Total, - - - - -	–	–	47.9	.368	4690
Dinner.					
Halibut steak, - - - - - -	2	–	36.0	.306	940
Potatoes, mashed, - - - - -	2	–	4.0	.034	620
Tomatoes, fresh, or equivalent from group 12, - - - - -	2	–	6.0	.018	210
Bread, - - - - - - -	–	12	3.0	.071	910
Butter, - - - - - - -	–	4	7.0	.002	880
Caramel custard (1 pint milk, 4 eggs, 2 oz. sugar), - - - - -	1	10	11.8	.099	980
Total, - - - - -	–	–	67.8	.530	4540
Supper or Lunch.					
Potato croquettes (1 quart potatoes, 3 eggs, 1 tablespoonful butter, 2 oz. bread crumbs, 1 oz. lard taken up in frying), - - - - -	2	10	13.0	.091	1755
Preserves, - - - - - - -	1	–	13.0	.008	1150
Bread, or equivalent from group 16, -	1	–	4.0	.094	1215
Butter, - - - - - - -	–	2	3.5	.001	440
Tea, - - - - - - - -	–	–	4.0	.008	250
Total, - - - - -	–	–	37.5	.202	4810
Total per day, - - - -	–	–	153.2	1.100	14040
Total for one man, - - -	–	–	38½	27½	3510

Menu No. 5.—For one day. For family equivalent in demands for food to four men at moderate muscular work.

BREAKFAST.

Cerealine, 4 oz.; milk, 6 oz.; sugar, 2 oz., pork chops, loin, or equivalent from group 5, 1½ lbs.; fried potatoes, 1 lb.; biscuit, or equivalent from groups 12 or 16, 12 oz.; butter, 2 oz.; coffee.

DINNER.

Beef chuck (boiled or roasted) 2 lbs.; mashed potatoes, 2 lbs.; green corn, 1 lb.; onions, or equivalent from group 10, 1 lb.; apple tart (¼ lb. flour, 2 oz. butter, 2 oz. sugar, 1 egg, 1½ lb. apples).

SUPPER.

Cheese fondu (1 lb. milk, 4 oz. bread crumbs, ½ lb. cheese, 3 eggs); hot rolls, or equivalent from group 16, 1 lb.; butter, 4 oz.; strawberries, or equivalent from group 14, 1 lb.; sugar, 3 oz.; tea.

Estimated cost, nutrients and energy of the above.

	Cost.	Protein.	Fuel Val.
	Cents.	Lbs.	Calories.
Breakfast,	31.2	.344	4885
Dinner,	38.5	.426	4615
Supper,	40.6	.353	5030
Total,	110.3	1.123	14530
For one man,	27½	.28	3630

Menu No. 6.—For one day. For family equivalent in demands for food to four men at moderate muscular work.

BREAKFAST.

Grapes, or equivalent from group 14, 1 lb.; wheatena, 4 oz.; milk, 6 oz.; sugar, 2 oz.; baked eggs (6 eggs, 4 oz. cracker crumbs); muffins (8 oz. flour, ½ pint milk, 2 eggs, 3 oz. butter, 2 oz. sugar); butter, 4 oz.; coffee.

DINNER.

Roast beef (rib), or equivalent from group 4, 2½ lbs.; mashed potatoes, 2 lbs.; turnips, or equivalent from group 12, 1 lb.; celery, or equivalent from group 13, ½ lb.; cheese, ¼ lb.; crackers, ¼ lb.

SUPPER.

Fried scallops, or equivalent from group 9, 1 lb.; French fried potatoes (1½ lbs. potatoes, 2 oz. lard); hot rolls, or equivalent from group 16, ¾ lb.; butter, 2 oz.; apricots (dried), or equivalent from group 14, ¼ lb.; sugar, ¼ lb.; tea.

Estimated cost, nutrients and energy of the above.

	Cost.	Protein.	Fuel Val.
	Cents.	Lbs.	Calories.
Breakfast,	44.3	.277	5280
Dinner,	53.5	.487	4655
Supper,	43.6	.272	3965
Total,	141.4	1.036	13900
For one man,	35½	.26	3475

Menu No. 7.—For one day. For family equivalent in demands for food to four men at moderate muscular work.

BREAKFAST.

Oatmeal, ¼ lb. (6 oz. milk, 2 oz. sugar); fried salt mackerel, 1½ lbs.; fried potatoes, 1 lb.; hot rolls, or equivalent from group 16, ¾ lb.; butter, 3 oz.; coffee.

DINNER.

Broiled sirloin steak, or equivalent from group 3, 2 lbs.; baked potatoes, 1½ lbs.; squash, or equivalent from group 12, 2 lbs.; bread, ¾ lb.; butter, 3 oz.; bananas, or equivalent from group 14, 1 lb.

SUPPER.

Oyster stew (1 pint oysters, 1 pint milk, 2 oz. butter); oyster crackers, ¼ lb.; bread, or equivalent from group 10, ½ lb.; butter, 1 oz.; currant jam, ½ lb.; sponge cake (3 eggs, 6 oz. sugar, 3 oz. flour); tea.

Estimated cost, nutrients and energy of the above.

	Cost.	Protein.	Fuel Val.
	Cents.	Lbs.	Calories.
Breakfast,	29.8	.366	4925
Dinner,	59.3	.474	4540
Supper,	50.6	.246	4535
Total,	139.7	1.086	14000
For one man,	35.0	.27	3500

Menu No. 8.—For one day. For family equivalent in demands for food to four men at moderate muscular work.

BREAKFAST.

Oranges, or equivalent from group 14, 2 lbs.; rolled oats, ¼ lb. (milk, 6 oz.; sugar, 2 oz.; omelette (8 eggs); johnny-cake, or equivalent from group 16, 1 lb.; butter, 3 oz.; coffee.

DINNER.

Corned beef (brisket), or equivalent from group 4, 2¼ lbs.; potatoes, 1 lb.; turnips, 1 lb.; cabbage, 1 lb.; beets, 1 lb.; bread, ¾ lb.; butter, 2 oz.; apple pie, ¾ lb.

SUPPER.

Cold corned beef, 1 lb.; French fried potatoes (1 lb. potatoes, 2 oz. lard); bread, or equivalent from group 16, ¾ lbs.; butter, 2 oz.; mixed pickles, ¼ lb.; sponge cake (3 eggs, 6 oz. sugar, 3 oz. flour); tea.

Estimated cost, nutrients and energy of the above.

	Cost.	Protein.	Fuel Val.
	Cents.	Lbs.	Calories.
Breakfast,	46.8	.277	3810
Dinner,	33.0	.511	5800
Supper,	29.9	.309	4800
Total,	109.7	1.097	14410
For one man,	27½	.27½	3600

Menu No. 9.—For one day. For family equivalent in demands for food to four men at moderate muscular work.

BREAKFAST.

Strawberries, or equivalent from group 14, 2 lbs.; sugar, 6 oz.; creamed fish (1 lb. halibut, ½ pint milk, 1 oz. flour, 1 oz. butter); baked potatoes, 1½ lbs.; hot rolls, or equivalent from group 16, ¾ lb.; butter, ¼ lb.; coffee.

DINNER.

Fricassee of lamb (chuck), or equivalent from group 5, 2½ lbs.; flour, 1 oz.; soda crackers, ¼ lb.; mashed potatoes, 2 lbs.; green peas, 1½ lbs.; radishes, or equivalent from group 13, ½ lb.; cracker pudding (1 pint milk, 2 eggs, 1½ oz. crackers, ½ oz. butter); lemon sauce (4 oz. sugar, ½ oz. cornstarch, ½ oz. butter, 1 oz. lemon).

SUPPER.

Mayonnaise of tomatoes and lettuce (1 lb. fresh tomatoes, 1 lb. lettuce, 3 oz. mayonnaise dressing); bread, or equivalent from group 16, 1 lb.; butter, ¼ lb.; sliced pineapple, 1 lb.; sugar, 6 oz.; iced tea.

Estimated cost, nutrients and energy of the above.

	Cost.	Protein.	Fuel Val.
	Cents.	Lbs.	Calories.
Breakfast,	50.8	.299	4770
Dinner,	57.4	.584	5785
Supper,	33.3	.199	3550
Total,	141.5	1.082	14105
For one man,	35½	.271	3525

Menu No. 10.—For one day. For family equivalent in demands for food to four men at moderate muscular work.

BREAKFAST.

Wheat "breakfast foods," ¼ lb.; milk, 6 oz.; sugar, 2 oz.; fried ham (smoked), 1½ lbs.; corncake, or equivalent from group 16, 1 lb.; butter, 3 oz.; coffee.

DINNER.

Split pea soup (14 oz. peas, 4 oz. ham); milk crackers, ¼ lb.; bread, ¾ lb.; butter, 2 oz.; Delmonico pudding (1 pint milk, 2 eggs, 1½ oz. cornstarch, 3 oz. sugar).

SUPPER.

Creamed dried beef (¾ lb. dried beef, chipped, ½ pint milk, 1 tablespoonful butter); bread, ¾ lb.; butter, 2 oz.; *spice cake, 1 lb.; canned peaches, 1 lb.; tea.

Estimated cost, nutrients and energy of the above.

	Cost.	Protein.	Fuel Val.
	Cents.	Lbs.	Calories.
Breakfast,	46.7	.346	5360
Dinner,	25.9	.411	4710
Supper,	48.6	.348	4215
Total,	121.2	1.105	14285
For one man,	30½	.276	3570

* In the computations one-third of the following receipt was used: Milk, ½ pint; brown sugar, ¾ lb.; flour, 10 oz.; butter, 4 oz.; 5 eggs.

The preceding menus are intended to show how the same nutritive value may be obtained in food combinations differing widely as regards the number, kind and price of the food materials used to make up three daily meals. They also illustrate how the cost of the daily food may vary with the kind and variety of materials purchased, though the nutritive value remains the same. They are not intended as in any sense "models" to be followed in actual practice. The food of any family will necessarily vary with the market supply, the season, and the relative expensiveness of different food materials, as well as the tastes and purse of the consumers. The main purpose is to draw especial attention to two points. One is that the prudent buyer of foods for family consumption can not afford to neglect the nutritive values. The other is the advantage of a well-balanced diet, and the ways by which it can be obtained.

By observing the markets many food materials can be purchased much cheaper than here indicated, while, on the other hand, there may be times when they will be much more expensive. The choice of vegetables and fruits, for instance, will naturally be governed by their abundance and cost.

It will be remembered that the quantities, and consequently the costs here given, are for a family equivalent in demand for nutriment to four men engaged in moderately hard muscular labor. Men with less muscular activity, women, and children need considerably less food, and different individuals differ greatly in their needs for food. These figures express only general averages and are based upon the best information accessible.

In the menu only such an amount of each food material is indicated as might be completely consumed at each meal. Of course in the ordinary household it is calculated that there will be a rather larger quantity of the different dishes prepared than will be consumed at one meal, but the thrifty housekeeper will see to it that what is not used at one meal will be saved for another.

Of course it is not expected that each meal, or the total food of each individual day, will have just the amounts of prot and fuel ingredients that make a well-balanced diet. The b[illegible] is continually storing nutritive materials and using them.

a repository of nutriment which is being constantly drawn upon, and as constantly resupplied. It is not dependent any day upon the food eaten that particular day. Hence an excess one day may be made up by a deficiency the next, or *vice versa*. Healthful nourishment requires simply that the nutrients as a whole during longer or shorter periods should be fitted to the actual needs of the body for use.

NOTE.—As an illustration of the statement made on page 177 above, that the cost of any given dietary will vary widely with circumstances, the following instance may be cited. It is taken from a letter which came to hand as the proof of this article was being corrected. The writer resides in the State of New York, and apparently is a farmer, or at least obtains his food materials at rates which would represent the cost to the farmer, who produces most of them on his farm. He represents himself as engaged in active muscular work, "being frequently on the move from four o'clock in the morning until nine at night." He gives the following figures for the kinds, amounts, and cost of food used by himself in one week:

Skim milk, 20 quarts; buttermilk, 1½ pints; cream, 2½ pints; butter, 1½ ounces; oatmeal, 2 pounds 10 ounces; corn meal, 2 pounds 15 ounces; entire wheat flour, 2 pounds 3 ounces; sugar, 6½ ounces; apples, 2 pounds 12½ ounces; raisins, 9½ ounces. These quantities of the different food materials should furnish not far from 163 grams of protein, 65 grams of fat, and 583 grams of carbohydrates, with a fuel value of 3665 calories per man per day. The cost of the different materials at the price actually paid was not quite 50 cents for the week, or 7 cents per day. Using the average prices given in table 43, on pages 174, 175, the cost would have been about $1.25, or 18 cents per day.

ANALYSES OF FOODS, FEEDING STUFFS, AND OTHER PRODUCTS.

REPORTED BY W. O. ATWATER AND F. G. BENEDICT.

In connection with the work of the Station during the year, analyses of the following miscellaneous foods, feeding stuffs, etc., have been made by the Station chemists. These analyses include those of food materials and other products made in connection with metabolism and digestion experiments with man, and those of feeding stuffs made in connection with the study of rations fed to milch cows. The methods of analysis were those recommended by the Association of Official Agricultural Chemists, with such minor modifications as have been found desirable.

FEEDING STUFFS.

The analyses reported in tables 44 and 45 beyond were made in connection with a study of rations fed to milch cows, the samples being taken from the materials in actual use by the respective dairymen whose herds were studied. In previous reports analyses of the forage plants grown in the experimental plots and of the feeding stuffs used in the sheep digestion experiments have also been given. As these experiments are not discussed in the present Report, but are reserved for future publication, no analyses connected with them are included in the following tables.

The results of the analyses as calculated to water content at the time of sampling are given in table 44, page 191. In this table the materials are grouped somewhat according to their water content at time of taking samples, as follows: Green fodders; silage; cured hay and fodder; grain; and milling and by-products.

The results calculated to water-free substance (dry matter) as the basis are given in table 45, pages 193, 194.

The fuel value of a pound of each of the feeding stuffs as given in the tables was obtained by multiplying the number of hundredths of a pound of protein and of carbohydrates by 18.6, and the number of hundredths of a pound of fat by 42.2, and taking the sum of these three products as the number of calories of available energy in the materials. We consider it important to insist here, as has been done elsewhere in this Report and other Reports, that the factors for fuel values here used, which are essentially those proposed by Rübner, are in no sense to be regarded as settled. These calculations of fuel values represent simply a preliminary effort to compare the feeding stuffs with respect to the quantities of energy they are capable of yielding to the body. The figures are by no means an exact measure of the nutritive effects of the food materials. We hope to discuss this matter more in detail in another place. The heats of combustion of the majority of the specimens were also made with the bomb calorimeter.

Two sets of averages are given in tables 44 and 45 beyond: the first is the average of the samples analyzed during the past year; the second is the average of all analyses of similar materials made up to the present time in this laboratory.

Description of samples.—No detailed description of samples is necessary in this place. The milling and by-products were such as are ordinarily found in the market. The cured fodders were such as are ordinarily cut and cured on Connecticut farms. The dairy tests, in connection with which the samples were taken, and the laboratory number of the samples analyzed with each test, are as follows:

In connection with dairy test No. 39 six samples of feeding stuffs were analyzed, namely Nos. 1783, 1784, 1785, 1786, 1787, 1788; with test No. 40, eight samples, Nos. 1792, 1793, 1794, 1795, 1796, 1797, 1798, 1799; with test No. 41, six samples, Nos. 1800, 1801, 1802, 1803, 1804, 1805; with test No. 42, seven samples, Nos. 1806, 1807, 1808, 1809, 1810, 1811, 1812; with test No. 43, eight samples, Nos. 1813, 1814, 1815, 1816, 1817, 1818, 1819, 1833; with test No. 44, five samples, Nos. 1820, 1821, 1822, 1823, 1824; with test No. 45, five samples, Nos. 1825, 1826, 1827, 1828, 1831; and with test No. 46, three samples, Nos. 1832, 1834, 1835.

TABLE 44.

Composition of fodders and feeding stuffs analyzed 1896–97. Calculated to water content at time of taking sample.

Lab. No.	FEEDING STUFFS.	Water.	Protein.	Fat.	Nit.-free Ext.	Fiber.	Ash.	Fuel Val. per Lb.
	Cured Fodders.	%	%	%	%	%	%	Cal.
1798	Corn stover, - -	8.4	4.2	2.3	48.8	29.9	6.4	1639
1806	Corn stover, - -	14.8	4.2	1.6	42.5	31.0	5.9	1512
1819	Corn stover, - -	22.5	5.6	1.5	36.8	28.6	5.0	1384
1826	Corn stover, - -	24.3	5.3	1.1	33.3	31.4	4.6	1348
	Average (4), - -	17.5	4.8	1.6	40.4	30.2	5.5	1469
	Avg. all analyses(178),	41.0	3.7	1.2	30.0	20.3	3.8	1055
1813	Oat straw, - - -	11.5	3.1	2.4	40.9	36.6	5.5	1600
1825	Oat straw, - - -	12.7	3.1	2.1	37.9	38.8	5.4	1572
	Avg. all analyses (2),	12.1	3.1	2.3	39.4	37.7	5.4	1589
1799	Hay, mixed grasses, -	7.0	7.1	3.1	49.9	27.0	5.9	1693
1801	Hay, mixed grasses, -	12.1	7.7	2.9	46.1	25.1	6.1	1590
1808	Hay, mixed grasses, -	11.8	7.1	2.8	48.9	24.2	5.2	1610
1823	Hay, mixed grasses, -	13.5	6.0	2.7	41.8	31.0	5.0	1580
1835	Hay, mixed grasses, -	7.3	7.6	4.5	50.1	26.3	4.2	1752
	Average (5), - -	10.3	7.1	3.2	47.4	26.7	5.3	1646
	Avg. all analyses (36),	12.2	7.7	3.0	44.1	27.7	5.3	1605
1822	Hay, second quality, -	15.3	7.4	3.3	44.9	23.3	5.8	1546
	Avg. all analyses (4),	12.0	8.9	2.9	43.4	27.2	5.6	1600
1783	Hay, meadow, - -	11.7	7.7	2.9	43.6	28.0	6.1	1597
	Avg. all analyses (2),	15.1	7.5	3.1	42.5	25.7	6.1	1540
1784	Hay, oat, - - -	10.0	6.7	2.2	44.5	31.1	5.5	1623
1802	Hay, oat, - - -	10.5	6.1	2.3	44.1	31.2	5.8	1611
1824	Hay, oat, - - -	12.2	8.0	3.0	41.7	30.0	5.1	1609
1834	Hay, oat, - - -	8.8	9.8	3.2	41.8	31.6	4.8	1683
	Average (4), - -	10.4	7.6	2.7	43.0	31.0	5.3	1632
	Avg. all analyses (16),	11.3	8.2	3.2	43.3	28.7	5.3	1627
	Ensilage.							
1788	Corn ensilage, - -	70.6	2.3	1.0	18.4	5.8	1.9	535
1792	Corn ensilage, - -	71.4	2.4	1.0	18.3	5.3	1.6	526
1800	Corn ensilage, - -	67.8	2.6	1.1	21.7	5.3	1.5	596
1812	Corn ensilage, - -	77.8	2.0	.9	13.9	4.2	1.2	412
	Average (4), - -	71.9	2.3	1.0	18.1	5.1	1.6	516
	Avg. all analyses (18),	74.6	2.0	.9	14.9	6.2	1.4	468
	Milling and By-Products.							
1785	Buffalo gluten feed, -	10.3	24.8	2.7	53.8	5.8	2.6	1683
1803	Buffalo gluten feed, -	9.6	25.7	2.9	53.4	5.8	2.6	1701
1820	Buffalo gluten feed, -	8.1	26.1	11.2	47.8	5.7	1.1	1952
	Average (3), - -	9.3	25.5	5.6	51.7	5.8	2.1	1780
	Avg. all analyses (9),	8.8	23.6	9.9	50.3	5.9	1.5	1902

TABLE 44.—*(Continued.)*

Lab. No.	Feeding Stuffs.	Water.	Protein.	Fat.	Nit.-free Ext.	Fiber.	Ash.	Fuel Val. per Lb.
		%	%	%	%	%	%	Cal.
1810	Chicago gluten meal, -	9.8	34.8	7.2	43.6	3.3	1.3	1823
1831	Chicago gluten meal, -	8.7	40.6	6.2	41.1	2.4	1.0	1825
1832	Chicago gluten meal, -	8.0	41.1	6.8	41.1	2.0	1.0	1853
	Average (3), - -	**8.8**	**38.8**	**6.8**	**41.9**	**2.6**	**1.1**	**1837**
	Avg. all analyses (10),	**8.7**	**36.4**	**6.5**	**44.7**	**2.7**	**1.0**	**1833**
1814	Rockford gluten feed, -	8.8	21.8	5.1	56.9	6.4	1.0	1798
1827	Rockford gluten feed, -	9.1	26.2	4.4	53.5	5.9	.9	1778
	Avg. all analyses (2),	**8.9**	**24.0**	**4.8**	**55.2**	**6.1**	**1.0**	**1790**
1787	Corn meal, - - -	15.2	10.0	4.4	66.4	1.3	2.7	1631
1797	Corn meal, - - -	14.6	7.8	3.8	71.5	1.1	1.2	1656
1811	Corn meal, - - -	14.1	8.4	4.4	70.6	1.1	1.4	1676
1817	Corn meal, - - -	12.2	9.7	4.4	71.0	1.3	1.4	1711
	Average (4), - -	**14.0**	**9.0**	**4.2**	**69.9**	**1.2**	**1.7**	**1667**
	Avg. all analyses (27),	**13.1**	**9.5**	**4.5**	**69.9**	**1.5**	**1.5**	**1695**
1818	Corn and cob meal, -	8.8	10.4	4.1	72.7	2.5	1.5	1765
1821	Corn and cob meal, -	16.2	8.8	3.5	66.0	4.1	1.4	1616
1833	Corn and cob meal, -	11.9	10.0	4.4	69.3	3.0	1.4	1717
	Average (3), - -	**12.3**	**9.7**	**4.0**	**69.4**	**3.2**	**1.4**	**1700**
	Avg. all analyses (18),	**12.9**	**9.7**	**4.1**	**68.4**	**3.4**	**1.5**	**1689**
1795	Cotton seed meal, -	5.7	47.9	15.3	19.7	4.6	6.8	1989
1805	Cotton seed meal, -	9.7	45.3	10.5	22.6	4.6	7.3	1791
1809	Cotton seed meal, -	7.0	48.0	14.9	19.9	3.8	6.4	1963
	Average (3), - -	**7.5**	**47.1**	**13.6**	**20.7**	**4.3**	**6.8**	**1914**
	Avg. all analyses (16),	**6.9**	**43.1**	**11.7**	**27.7**	**3.8**	**6.8**	**1881**
1794	Ground oats, - -	7.6	13.2	6.9	62.3	6.4	3.6	1815
1815	Fine wheat feed, - -	11.1	19.3	5.2	53.5	6.7	4.2	1697
1816	Linseed oil meal, -	7.5	39.2	8.3	31.2	8.7	5.1	1821
	Avg. all analyses (11),	**10.1**	**34.3**	**5.5**	**36.9**	**7.7**	**5.5**	**1700**
1793	Rye meal, - - -	10.7	11.0	2.0	73.2	1.5	1.6	1678
	Avg. all analyses (3),	**11.4**	**11.9**	**2.2**	**70.1**	**2.3**	**2.1**	**1660**
1796	Wheat bran, - -	8.5	14.5	4.7	54.1	13.0	5.2	1717
1804	Wheat bran, - -	16.9	15.4	5.3	51.7	6.5	4.2	1593
1807	Wheat bran, - -	11.5	13.8	3.7	55.7	10.2	5.1	1639
1828	Wheat bran, - -	11.4	15.8	6.9	48.4	11.6	5.9	1701
	Average (4), - -	**12.1**	**14.9**	**5.1**	**52.5**	**10.3**	**5.1**	**1660**
	Avg. all analyses (42),	**9.6**	**17.1**	**5.1**	**53.5**	**9.2**	**5.5**	**1699**
1786	Potatoes, - - -	81.9	1.9	.2	14.3	.6	1.1	321

TABLE 45.

Composition of water-free substance of fodders and feeding stuffs analyzed 1896–97.

Lab. No.	FEEDING STUFFS.	Protein.	Fat.	Nit.-free Ext.	Fiber.	Ash.	Fuel Val. per Lb.
	Cured Fodders.	%	%	%	%	%	Cal.
1798	Corn stover, - - -	4.53	2.50	53.24	32.70	7.03	1785
1806	Corn stover, - - -	4.99	1.90	49.82	36.35	6.94	1775
1819	Corn stover, - - -	7.24	1.96	47.43	36.92	6.45	1790
1826	Corn stover, - - -	7.05	1.50	43.93	41.45	6.07	1780
	Average (4), - - -	**5.95**	**1.97**	**48.60**	**36.86**	**6.62**	**1785**
	Average all analyses (178),	**6.39**	**1.98**	**50.98**	**34.25**	**6.40**	**1785**
1813	Oat straw, - - - -	3.56	2.67	46.17	41.40	6.20	1805
1825	Oat straw, - - - -	3.58	2.40	43.43	44.39	6.20	1800
	Average all analyses (2), -	**3.57**	**2.54**	**44.80**	**42.89**	**6.20**	**1800**
1799	Hay, mixed grasses, - -	7.58	3.36	53.70	29.00	6.36	1820
1801	Hay, mixed grasses, - -	8.77	3.27	52.48	28.52	6.96	1805
1808	Hay, mixed grasses, - -	8.01	3.22	55.42	27.44	5.91	1825
1823	Hay, mixed grasses, - -	6.97	3.07	48.37	35.87	5.72	1825
1835	Hay, mixed grasses, - -	8.16	4.85	54.03	28.45	4.51	1890
	Average (5), - - -	**7.90**	**3.55**	**52.80**	**29.86**	**5.89**	**1835**
	Average all analyses (36), -	**8.79**	**3.39**	**50.19**	**31.55**	**6.08**	**1825**
1822	Hay, second quality, - -	8.72	3.90	52.95	27.54	6.89	1825
	Average all analyses (4), -	**10.04**	**3.35**	**49.37**	**30.80**	**6.44**	**1820**
1783	Hay, meadow, - - -	8.68	3.25	49.44	31.71	6.92	1805
	Average all analyses (2), -	**8.84**	**3.65**	**50.20**	**30.17**	**7.14**	**1815**
1784	Hay, oat, - - - -	7.49	2.45	49.43	34.57	6.06	1805
1802	Hay, oat, - - - -	6.88	2.57	49.24	34.86	6.45	1800
1824	Hay, oat, - - - -	9.14	3.35	47.52	34.22	5.77	1835
1834	Hay, oat, - - - -	10.74	3.51	45.83	34.67	5.25	1845
	Average (4), - - -	**8.56**	**2.97**	**48.01**	**34.58**	**5.88**	**1820**
	Average all analyses (16), -	**9.29**	**3.58**	**48.92**	**32.21**	**6.00**	**1830**
	Ensilage.						
1788	Corn ensilage, - - -	7.73	3.62	62.42	19.76	6.47	1825
1792	Corn ensilage, - - -	8.31	3.53	64.14	18.42	5.60	1840
1800	Corn ensilage, - - -	8.09	3.37	67.57	16.36	4.61	1850
1812	Corn ensilage, - - -	9.19	4.15	62.35	18.87	5.44	1855
	Average (4), - - -	**8.33**	**3.67**	**64.12**	**18.35**	**5.53**	**1840**
	Average all analyses (18), -	**7.98**	**3.56**	**57.27**	**25.43**	**5.76**	**1835**
	Milling and By-Products.						
1785	Buffalo gluten feed, - -	27.63	3.03	60.00	6.44	2.90	1875
1803	Buffalo gluten feed, - -	28.47	3.15	59.07	6.41	2.90	1880
1820	Buffalo gluten feed, - -	28.43	12.25	51.99	6.16	1.17	2125
	Average (3), - - -	**28.18**	**6.14**	**57.02**	**6.34**	**2.32**	**1960**
	Average all analyses (9), -	**25.87**	**10.80**	**55.21**	**6.53**	**1.59**	**2080**

TABLE 45.—*(Continued.)*

Lab. No.	FEEDING STUFFS.	Protein.	Fat.	Nit.-free Ext.	Fiber.	Ash.	Fuel Val. per Lb.
		%	%	%	%	%	Cal.
1810	Chicago gluten meal, - -	38.54	8.01	48.41	3.63	1.41	2020
1831	Chicago gluten meal, - -	44.48	6.76	45.03	2.63	1.10	2000
1832	Chicago gluten meal, - -	44.71	7.41	44.66	2.13	1.09	2015
	Average (3), - - -	**42.58**	**7.39**	**46.03**	**2.80**	**1.20**	**2010**
	Average all analyses (10), -	**39.96**	**7.06**	**48.98**	**2.92**	**1.08**	**2010**
1814	Rockford gluten feed, - -	23.96	5.55	62.42	6.99	1.08	1970
1827	Rockford gluten feed, - -	28.83	4.80	58.89	6.45	1.03	1955
	Average all analyses (2), -	**26.39**	**5.18**	**60.65**	**6.72**	**1.06**	**1960**
1787	Corn meal, - - - -	11.82	5.17	78.26	1.50	3.25	1925
1797	Corn meal, - - - -	9.17	4.43	83.65	1.28	1.47	1935
1811	Corn meal, - - - -	9.84	5.08	82.22	1.23	1.63	1950
1817	Corn meal, - - - -	11.11	5.02	80.87	1.46	1.54	1950
	Average (4), - - -	**10.49**	**4.93**	**81.26**	**1.37**	**1.95**	**1940**
	Average all analyses (27), -	**10.98**	**5.15**	**80.41**	**1.74**	**1.72**	**1950**
1818	Corn and cob meal, - -	11.38	4.50	79.68	2.78	1.66	1935
1821	Corn and cob meal, - -	10.57	4.14	78.74	4.90	1.65	1925
1833	Corn and cob meal, - -	11.42	4.98	78.64	3.36	1.60	1945
	Average (3), - - -	**11.13**	**4.54**	**79.01**	**3.68**	**1.64**	**1935**
	Average all analyses (18), -	**11.14**	**4.72**	**78.51**	**3.91**	**1.72**	**1940**
1795	Cotton seed meal, - -	50.85	16.18	20.90	4.87	7.20	2110
1805	Cotton seed meal, - -	50.19	11.58	25.06	5.12	8.05	1985
1809	Cotton seed meal, - -	51.67	16.01	21.37	4.09	6.86	2110
	Average (3), - - -	**50.90**	**14.59**	**22.44**	**4.70**	**7.37**	**2065**
	Average all analyses (16), -	**46.33**	**12.57**	**29.72**	**4.04**	**7.34**	**2020**
1794	Ground oats, - - -	14.34	7.47	67.42	6.88	3.89	1965
1815	Fine wheat feed, - - -	21.70	5.78	60.20	7.57	4.75	1910
1816	Linseed oil meal, - - -	42.45	8.93	33.71	9.41	5.50	1965
	Average all analyses (11), -	**38.12**	**6.14**	**41.02**	**8.55**	**6.17**	**1890**
1793	Rye meal, - - - -	12.24	2.27	82.00	1.67	1.82	1880
	Average all analyses (3), -	**13.39**	**2.47**	**79.23**	**2.59**	**2.32**	**1875**
1796	Wheat bran, - - -	15.85	5.09	59.09	14.28	5.69	1875
1804	Wheat bran, - - -	18.52	6.45	62.19	7.80	5.04	1915
1807	Wheat bran, - - -	15.63	4.22	62.92	11.50	5.73	1850
1828	Wheat bran, - - -	17.81	7.82	54.61	13.13	6.63	1920
	Average (4), - - -	**16.95**	**5.90**	**59.70**	**11.68**	**5.77**	**1890**
	Average all analyses (42), -	**18.81**	**5.63**	**59.29**	**10.18**	**6.09**	**1880**
1786	Potatoes, - - - -	10.29	1.33	79.18	3.43	5.77	1785

ANALYSES OF FOOD MATERIALS.

In the Report of this Station for 1891 the results of some 325 analyses of materials used as food of man were given. Since then not far from 1,000 specimens of such food materials have been analyzed by the Station. The results of these analyses have not been published in detail, because of the large expense of such printing in the reports of the Station, and the hope that a place would be found for them in Government publications where they would have a wider circulation. An especial reason for such publication is found in the fact that a considerable share of the analyses were made in the course of inquiries carried out by the Station in coöperation with the Government. This was true of some 600 analyses of food materials collected at the World's Fair in Chicago in 1893. But while the details are still unpublished the final results have been included in summaries published by the Station,* and more especially by the U. S. Department of Agriculture.† Partial reports of some of the analyses have been published in connection with accounts of dietary studies and digestion or metabolism experiments in connection with which the analyses were made.

The Station has also analyzed from year to year considerable numbers of feeding stuffs in connection with experiments upon the effects of fertilizers on the growth and composition of crops, and feeding and digestion experiments with cows and sheep. The results of these analyses have been given in the Reports of the Station. In the present Report it has seemed best to include the results of all the analyses, both of foods and feeding stuffs, made during the year 1896–97 in connection with investigations published in the present Report. The food materials were those used in the digestion and metabolism experiments with men, described elsewhere in the present Report.

Table 46 shows the composition of the food materials at the time of sampling, and table 47 the composition of the same when calculated to the water-free basis, *i. e.*, the composition of the dry matter. The heats of combustion were determined in the bomb calorimeter. It is to be noted that the fuel values

* See Report for 1896, pp. 190–204.

† Bulletin 28 of the Office of Experiment Stations of the U. S. Department of Agriculture on "The Composition of American Food Materials."

would be somewhat less than the heats of combustion, as explained on page 155.

TABLE 46.

Composition of food materials analyzed 1896–97. Calculated to water content at time of taking sample.

Lab. No.	FOOD MATERIALS.	Water.	Protein.	Fat.	Carbo-hydrates.	Ash.	Heat of Combustion Per Gram.
		Per Ct.	Per Ct.	Per Ct.	Per Ct.	Per Ct.	Cal.
2782	Beef, fried, - - -	64.21	28.69	5.51	—	1.77	2.108
2789	Beef, fried, - - -	60.29	29.81	8.69	—	2.09	2.421
2795	Beef, fried, - - -	66.85	25.49	6.69	—	1.27	2.010
2820	Beef, fried, - - -	60.27	27.54	10.44	—	2.18	2.479
2821	Beef, fried, - - -	59.78	31.64	7.06	—	1.70	2.410
2783	Beef, dried, - - -	60.15	24.55	7.83	—	7.60	2.028
2796	Beef, dried, - - -	65.37	24.46	2.79	—	7.17	1.595
2788	Ham, deviled, - -	42.22	16.48	36.85	—	4.03	4.353
2781	Eggs, boiled, - -	74.53	12.63	10.97	—	.94	1.778
2790	Eggs, boiled, - -	73.25	13.99	11.30	—	.98	1.928
2798	Eggs, boiled, - -	74.51	12.43	10.84	—	.99	1.808
2818	Eggs, boiled, - -	74.34	12.37	10.85	—	1.02	1.796
2819	Eggs, boiled, - -	79.91	9.98	9.07	—	.71	1.424
2785	Butter, - - -	8.05	1.08	88.33	—	2.54	8.052
2793	Butter, - - -	9.35	.99	87.27	—	2.39	7.954
2801	Butter, - - -	9.76	1.19	85.88	—	3.17	7.929
2827	Butter, - - -	10.02	1.54	85.19	—	3.25	7.777
2784	Milk, - - - -	85.28	3.63	5.39	4.92	.78	.891
2799	Milk, - - - -	85.27	3.00	5.40	5.64	.69	.935
2800	Milk, - - - -	87.05	3.50	4.80	3.87	.78	.742
2826	Milk, - - - -	85.01	3.44	5.12	5.80	.63	.902
2803	Bread, white, - -	43.87	8.30	1.62	44.97	1.24	2.540
2802	Bread, rye, - - -	43.97	8.54	.28	45.65	1.56	2.418
2804	Bread, rye, - - -	42.40	8.37	.58	47.05	1.60	2.483
2814	Bread, rye, - - -	36.83	9.98	.36	51.14	1.69	2.769
2815	Bread, rye, - - -	37.11	9.86	.13	51.17	1.73	2.748
2786	Sugar, - - - -	—	—	—	100.00	—	3.963
2780	Beans, baked, - -	68.79	7.86	.59	20.61	2.15	1.341
2791	Beans, baked, - -	71.45	7.16	.38	19.15	1.86	1.222
2797	Beans, baked, - -	70.92	6.21	.95	19.95	1.97	1.257
2822	Apples, - - -	85.42	.27	.56	13.48	.27	.585
2823	Apples, - - -	84.73	.23	.52	14.21	.31	.617
2779	Pears, canned, - -	79.56	.28	.91	19.00	.25	.778
2792	Pears, canned, - -	81.42	.33	.14	17.87	.24	.759

TABLE 47.

Composition of water-free substance of food materials analyzed 1896–97.

Lab. No.	Food Materials.	Protein.	Fat.	Carbo-hydrates.	Ash.	Heat of Combustion Per Gram.
		Per Ct.	Per Ct.	Per Ct.	Per Ct.	Cal.
2782	Beef, fried,	80.15	15.41	—	4.94	5.890
2789	Beef, fried,	75.06	21.87	—	5.28	6.095
2795	Beef, fried,	76.88	20.17	—	3.83	6.065
2820	Beef, fried,	69.33	26.26	—	5.50	6.239
2821	Beef, fried,	78.69	17.56	—	4.21	5.993
2783	Beef, dried,	61.61	19.65	—	19.07	5.090
2796	Beef, dried,	70.63	8.06	—	20.69	4.610
2788	Ham, deviled,	28.52	63.78	—	6.97	7.535
2781	Eggs, boiled,	49.58	43.05	—	3.69	6.980
2790	Eggs, boiled,	52.30	42.24	—	3.66	7.205
2798	Eggs, boiled,	48.77	42.55	—	3.88	7.095
2818	Eggs, boiled,	48.24	42.30	—	3.95	6.999
2819	Eggs, boiled,	49.67	45.13	—	3.55	7.085
2785	Butter,	1.17	96.07	—	2.76	8.760
2793	Butter,	1.09	96.27	—	2.64	8.775
2801	Butter,	1.32	95.17	—	3.51	8.790
2827	Butter,	1.71	94.68	—	3.61	8.644
2784	Milk,	24.66	36.62	33.42	5.30	6.055
2799	Milk,	20.37	36.66	38.29	4.68	6.350
2800	Milk,	27.03	37.07	29.88	6.02	5.730
2826	Milk,	22.95	34.16	38.69	4.20	6.018
2803	Bread, white,	14.78	2.90	80.12	2.20	4.525
2802	Bread, rye,	15.23	.50	81.49	2.78	4.315
2804	Bread, rye,	14.53	1.00	81.69	2.78	4.310
2814	Bread, rye,	15.79	.57	80.96	2.68	4.385
2815	Bread, rye,	15.69	.21	81.36	2.74	4.369
2786	Sugar,	—	—	100.00	—	3.963
2780	Beans, baked,	25.20	1.88	66.04	6.88	4.300
2791	Beans, baked,	25.09	1.35	67.06	6.50	4.280
2797	Beans, baked,	21.34	3.28	68.62	6.78	4.325
2822	Apples,	1.85	3.84	92.47	1.84	4.015
2823	Apples,	1.49	3.43	93.03	2.05	4.038
2779	Pears, canned,	1.37	4.46	92.95	1.22	3.805
2792	Pears, canned,	1.80	.75	96.18	1.27	4.085

Description of samples.—The laboratory numbers of food materials given in the preceding tables are those used in the description of the digestion experiments, pp. 159–167:

Beef, fried.—This was round steak freed from all visible fat and passed through one of the ordinary forms of meat cutters. It was then fried, any fat that tried out during the cooking being discarded.

Beef, dried.—Ordinary smoked dried beef as found in the market.

Deviled Ham.—Underwood & Underwood's, packed in ¼-pound cans.

Eggs.—These were "hard boiled" in every instance. There was no apparent loss in weight during boiling.

Butter.—Creamery butter as purchased in the market.

Milk.—Fresh milk from a mixed herd.

Bread.—Both the wheat and rye breads were purchased at a local bakery.

Sugar.—Ordinary granulated white sugar.

Baked beans.—Canned with a very small piece of pork.

Apples.—Fresh fruit.

Pears.—Canned halves with syrup.

In connection with the digestion experiments described on pages 154 to 167 above, the intestinal secretions were analyzed with results as given in the following table:

TABLE 48.

Composition of feces from digestion experiments.

Lab. No.	FECES.	Water.	Protein.	Fat.	Carbo-hydrates.	Ash.	Heat of Combustion Per Gram.
	Calculated to water content of fresh sample.	PerCt.	PerCt.	PerCt.	PerCt.	PerCt.	Cal.
2805	From digestion experiment No. 37,	74.23	9.03	5.86	5.69	5.19	1.354
2806	From digestion experiment No. 38,	78.16	8.20	4.49	5.12	4.03	1.141
2807	From digestion experiment No. 39,	72.31	9.72	5.88	7.32	4.77	1.578
2808	From digestion experiment No. 40,	78.55	8.05	4.12	5.64	3.64	1.194
2809	From digestion experiment No. 41,	71.44	11.79	5.38	6.63	4.76	1.564
2810	From digestion experiment No. 42,	70.96	11.30	4.95	7.63	5.16	1.530
2824	From digestion experiment No. 43,	72.92	9.87	5.19	7.19	4.83	1.429
2825	From digestion experiment No. 44,	69.75	11.08	5.90	7.68	5.59	1.643
	Water-free substance.						
2805	From digestion experiment No. 37,	—	35.03	22.74	22.07	20.16	5.250
2806	From digestion experiment No. 38,	—	18.81	20.57	42.16	18.46	5.225
2807	From digestion experiment No. 39,	—	35.11	21.23	26.44	17.22	5.700
2808	From digestion experiment No. 40,	—	37.52	19.20	26.30	16.98	5.565
2809	From digestion experiment No. 41,	—	41.28	18.85	23.20	16.67	5.480
2810	From digestion experiment No. 42,	—	38.92	17.03	26.27	17.78	5.270
2824	From digestion experiment No. 43,	—	36.43	19.17	26.56	17.84	5.280
2825	From digestion experiment No. 44,	—	36.63	19.52	25.38	18.47	5.430

IMPROVED FORMS OF BOMB CALORIMETER AND ACCESSORY APPARATUS.

BY W. O. ATWATER AND O. S. BLAKESLEE.

A previous Report of this Station gave an account of a bomb calorimeter which had been found useful for determining the heats of combustion of organic substances including foods and feeding stuffs.* In the experiments carried on by this Station on the food and nutrition of animals and men, this apparatus has been in constant use for several years and the experience has led to a number of improvements in the apparatus, accessories, and manipulation. The need of such an apparatus is coming to be more and more widely felt. A number of laboratories are now using it, and the inquiries regarding it are constantly coming to us from investigators in this country and in

* A New Form of Bomb Calorimeter, by W. O. Atwater and Chas. D. Woods. Report of the Storrs (Conn.) Experiment Station for 1894, p. 135.

The article describes briefly the bomb of Berthelot, and explains the only difficulty in the way of its use, namely, the high cost due to the large amount of platinum used in the lining and cover. The price of the bomb and accessories in 1893 was about $1,200. The following statements are taken from the article:

" Various modifications of Berthelot's apparatus have been devised especially to " obviate the difficulty of expensive lining. Mahler uses a bomb of forged steel with " enamel lining. (Compt. rend., 113, 774, and 862, and Génie Civile, Jan. 23, 1892, " p. 198. See also Zeitsch. f. anal. Chem., 1893, 79, and Berthelot, Calorimétrie Chimique, " 133.) The cylinder is somewhat narrowed at the top and the cover is screwed directly " upon it, the junction being made tight by a washer or gasket of lead. The enamel " is easily put on or replaced, and it is stated that a single coating has been used for " 300 combustions without injury. It has been frequently found, however, that the " enamel scales off in constant use. The form described by Mahler has an internal " capacity of 600 cubic centimeters, or nearly double that of Berthelot's bomb, as above " described."

" Prof. Hempel of Dresden uses, for determination of heats of combustion of coal, " a simple bomb of steel without lining. The principle, like that of Mahler's form, is " the same as that of Berthelot. The closure is by a ' head piece ' which screws into " the neck of the bomb. It suffices very well for technical purposes, but is not recom- " mended for scientific use. (Hempel, Gasanlytische Methoden, 1890, 355, and Eng- " lish translation, Methods of Gas Analysis, 1892, p. 359.)"

" In accordance with suggestions by one of us (W. O. A.) during a sojourn in Dres- " den, Prof. Hempel most kindly had a bomb made by the mechanicians who make " the bombs of his devising just referred to, and lined, by Heraeus of Hanau, with a " thin sheet of platinum. Through Prof. Hempel's painstaking care, added to his " inventive skill and his peculiarly thorough familiarity with the whole subject, an " apparatus was obtained which has proved most efficient. The principle is the same " as in Berthelot's form; but whereas the cover of Berthelot's fits into the cylinder in " the manner of a very wide stopper, the cover in this, as in Mahler's, rests directly " upon the upper edge of the cylinder, a projection of the latter fitting into a groove " of the former. A washer of lead is set in the groove of the cover, the latter is held " tightly to the cylinder by a screw cap or collar and thus perfect closure is easily " secured."

Experience since that article was written has led to further improvements in the bomb and accessory apparatus. A number of the improvements in the bomb, and especially the new forms of accessory apparatus, have been devised by Mr. Blakeslee, Mechanician of Wesleyan University, by whom the whole apparatus is now made. Valuable suggestions have been made by Prof. C. D. Woods. W. O. A.

Europe. It seems desirable, therefore, to describe the apparatus with its later modifications. The brevity of the present description is warranted by the fact that the apparatus in its present form is similar to that previously described, and that a detailed account of both the apparatus and the methods of manipulation as here employed is now being prepared for publication in another place.

THE APPARATUS AND METHOD.

The method consists essentially in burning the substance in excess of oxygen at high pressure in a bomb immersed in water, the heat of combustion being determined by the rise in the temperature of the water. The apparatus consists of:

1. A bomb of steel with platinum lining. This is provided with platinum capsules to hold the substance to be burned, platinum supports for the capsules, and connections for igniting the substance by an electric current.

2. Calorimeter cylinders and thermometric apparatus. These include: A water-holding cylinder of britannia or "white metal," two larger concentric cylinders of indurated fibre, with hard rubber covers, a device for stirring the water in the metal calorimeter cylinder, thermometer, and thermometer-support.

3. Accessory apparatus, including clamp and spanner for opening and closing bomb, cylinder for oxygen, support for bomb when being filled, pipe connections, and couplings to connect bomb with oxygen cylinder, and manometer to show oxygen pressure in cylinder and in bomb.

4. Battery, for running motor which actuates water stirrer, and also for firing bomb. Such a battery is recommended only when a better source of electric current is not available.

THE BOMB.

The bomb consists of three parts: A cylinder to contain the substance to be burned and the oxygen for combustion, a cover to close the cylinder, and a threaded ring or collar to hold the cover tightly on the cylinder. The parts are shown separately in Fig. 1, and in cross section, as put together in Fig. 2, A being the cylinder, B the cover, and C the collar.

The cylinder is of Hotchkiss gun tool steel, kindly furnished by the Bethlehem Iron Company, who have favored us with

tests of "oil-tempered forgings made from the same steel and at about the same time the bars were made" which were used for the later bombs. These latter tests "were many in number, and an average taken from them gives the following results":

Tensile strength, - - - - -	85,514 lbs. per sq. in.
Elastic limit, - - - - - -	47,366 lbs. per sq. in.
Extension, - - - - - -	23.82 per cent.
Contraction, - - - - - -	43.05 per cent.

The cover, collar, and screws are of the best tool steel. In the apparatus as now made the inside dimensions of the cylinder are, approximately: Depth, 12.7 cm.; diameter, 6.3 cm. at top and 5.9 cm. at bottom. The wall is approximately .6 cm. in thickness. The weight of the whole bomb is not far from 3,200 grams, and its capacity nearly 380 cc.

FIG. 1.—PARTS OF THE BOMB.

The cover is provided with a neck (D). Into this fits, at the top, a cylindrical screw (E), into which in turn fits a valve screw (F). In the neck (D), where the bottom of the cylinder screw (E) rests, is a shoulder fitted with a packing of lead (L). The pressure on this packing makes a tight closure upon the part of F which it surrounds. On the side of D is an opening (G), into which may be screwed the coupling connecting the tube with the receptacle which holds the oxygen used for the combustion. The coupling when screwed in thrusts against a washer of lead at the end of G, which insures perfect closure. A narrow passage runs horizontally to a point just above the valve seat in the center of D. A similar passage runs from the apex of the valve seat perpendicularly downwards through the cover. These two passages provide a channel for the oxygen

to pass into the interior of the bomb. This channel may be tightly closed by the valve screw, the lower end of which is conical and thrusts against the inner surface of D, the angle of which at the place of contact corresponds to that of the tip of the screw. Between the top of the valve seat and the bottom of the packing (L), the valve screw fits so closely in the cover as to prevent the lead of the packing from working downward and thus obstructing the small gas passages.

The upper edge of A is beveled on both sides; the apex is rounded, and fits into a gasket (K) of lead, which is held in a groove in the cover (B). With use the metal gradually flows out of the groove under the heavy pressure so that the gaskets have to be replaced occasionally. The gaskets are easily made and extra ones are furnished with each bomb. One difficulty in screwing the collar down tightly enough to prevent the escape of gas between the edge of the cylinder and the gasket, at the high pressure to which the gases are subjected, is the friction of the collar upon the cover. To accomplish this the cylinder of the bomb is put in a clamp especially devised for the purpose and described beyond. The collar is turned by a long spanner, the projection of which fits into the two depressions shown in the collar at PP. The attempt was made to replace the lead gaskets by a harder metal which would stand heavier pressure without flowing. Copper and an alloy of tin, antimony and copper were tried. To avoid the friction between the collar and cover induced by the very heavy pressure, ball bearings were used as described in the previous account of the bomb. Experience has, however, shown that the lead gaskets are preferable and the ball bearings are discarded.

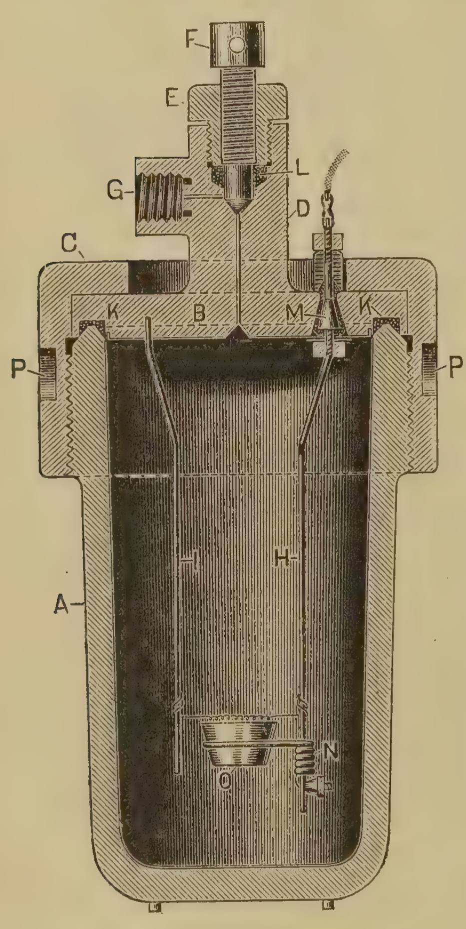

FIG. 2.—CROSS SECTION OF BOMB.

The platinum wires, H and I, inside the bomb, serve to hold a platinum capsule (O) containing the substance to be burned

and to conduct an electric current. Of these two wires one, I, is screwed into the cover; the other, H, passes through a conical hole in the cover.

The method of insulating the wire (H) which conducts the current through the cover of the bomb at M, Fig. 2, is shown in Fig. 3. In the bomb cover, a section of which is shown at A, is a conical hole. The larger end of the hole is on the inside of the cover. Into this hole fits a German silver cone (B). This is practically an enlargement of the small rod (C) which projects above the cover and serves for the electrical connection. The platinum wire (D) is gold soldered into the lower end of the cone, thus making a continuous conductor (C, B, D). To insulate this conductor a piece of rubber tubing is fitted over the cone. The rubber tube is long enough so that it can be stretched out, as the cone (B) is drawn into the cover; the surplus rubber tube is then cut off at E, and over the rod (C) is placed the hard rubber sleeve (F), and the nut (G) is tightened down until the conductor (C, B, D), is firm in the cover. To prevent the burning of the rubber insulation on the inside of the bomb, and to prevent leakage of current due to the conductivity of the nitric acid formed in the combustion, a mica disk (H) is placed over the platinum wire (D), and held against the platinum lining of the cover by the platinum nut (I). If a little space is left at the large end of the cone not filled by the end of the rubber tubing it is filled up with a mixture of fine asbestos fiber and shellac, which is allowed to dry before the mica disk (H) is secured in place.

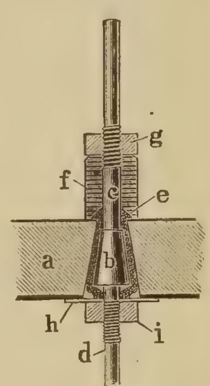

FIG. 3. METHOD OF INSULATION.

Near the lower end of H is a platinum wire (N, Fig. 2), bent in the form of a ring to hold the platinum capsule, and coiled about the wire, to which it is held by a screw. When a combustion is made the two platinum wires are connected by a very fine iron wire which passes over the crucible. The part directly above the substance to be burned is bent into a spiral, thus furnishing a larger quantity of iron to be ignited and, falling, to ignite the substance in the crucible.

Three small pins on the bottom of the bomb, of which two are shown in the diagram, support it when standing

upright. Their diameter is small in order to provide for the minimum passage of heat from the bomb to the water-holding cylinder, so that the amount directly communicated to the latter shall not be large enough to interfere with the accuracy of the determination. We have lately observed, in special experiments made for the purpose, that when substances are burned in the bomb the lower portion of the latter is but slightly warmed. As the pins are decidedly inconvenient in many ways, the feasibility of dispensing with them entirely or providing a more convenient substitute is under consideration.

Lining of the bomb.—It is necessary that the inner surface of the cylinder and cover be protected from the oxidizing action of both the oxygen at the high temperature of the combustion and the nitric (nitrous?) acid formed. The most convenient protection is a lining of platinum. In the bomb as devised by Berthelot the amount of platinum in the lining and in the stopper which serves as cover is very large, and at the present price of platinum so costly as to put the apparatus beyond the reach of most investigators.

An essential feature of the bomb here described is the use of a thin lining of platinum for both cylinder and cover. The cover is lined with sheet platinum. In the one previously described the lining of the cylinder was a cup made of sheet platinum. This was made by rolling a sheet into a cylinder of proper size, gold soldering the seam, pressing a circular disk into proper form for the bottom, and gold soldering it to the cylinder. The upper end was stiffened by a thicker ring of platinum, and the whole made to fit the cylinder. This cup served the purpose most satisfactorily, but, as would be expected, the gold-soldered seams showed a weakness with use, and frequent repairs became necessary. A seamless cup of platinum thus proved desirable, and experiments were instituted by Messrs. Baker & Co., of Newark, N. J., who succeeded in spinning from one piece of platinum a cup which accurately fits a cylinder of the dimensions above given. The corners at the bottom are rounded for convenience in spinning and in use. One of the cups thus spun proved somewhat porous, but Messrs. Baker & Co. have found means for avoiding this difficulty. The mechanical skill which has given so successful a result seems to us fortunate as it is noteworthy.

While this lining has proved very satisfactory not only here, but in several other laboratories as well, the expense of the platinum is still an objection, and numerous attempts have been made to find a cheaper substitute. The attempt of Berthelot* to electroplate the inside surface with gold did not give satisfactory results. Prof. H. W. Wiley, who has used the apparatus here described, and has published a method for determining the hydrothermal equivalent,† has also made experiments with a plating of gold, but it has not proven satisfactory when plated, either directly on the steel or with an intervening layer of copper. There are apparently two difficulties with the plated lining, one is that it is somewhat porous even when carefully burnished, and the oxygen under heavy pressure penetrates to the steel. Another is the unequal expansion of the thin lining and the thicker wall of steel when the interior is suddenly heated by combustion.

The use of a thin, gold-plated cup of copper, or other metal, is under consideration, but we have not yet put it to a practical test. We have, however, made attempts to use cups of aluminum spun from sheets of the purest metal we could obtain, but have met the difficulty that the aluminum is attacked by nitric acid, the amount dissolved being sufficient to interfere with the accuracy of the determinations. That aluminum was dissolved in appreciable quantities was shown by loss in weight of the cup.

It is perhaps possible that an enamel may be found which will stand the strain of heating and expansion. This would solve the rather perplexing problem of an inexpensive lining.

THE CALORIMETER CYLINDERS.—THERMOMETRIC APPARATUS.

The bomb when ready for a combustion is immersed in water contained in a metal cylinder. This cylinder is surrouunded by concentric cylinders or pails of "indurated fiber," leaving air spaces to prevent undue passage of heat between the water and the outer air. The arrangement is shown in Fig. 4. The cylinder is of britannia metal 12 cm. in diameter, 22 cm. high, and holding, with the bomb, not far from 1,700 grams of water. A stirrer (SS) moved by a small motor or other agency, keeps the water in motion and insures the mixing needed for equalizing its temperature. The calorimeter cylinder stands on

* Ann. Chim. Phys. (5), 23, 161. † Jour. Am. Chem. Soc., Vol. XIX., p. 439.

supports which prevent it from coming in contact with the bottom of the pail. The pails are provided with covers of hard rubber or indurated fiber. The diameters of the pails are such

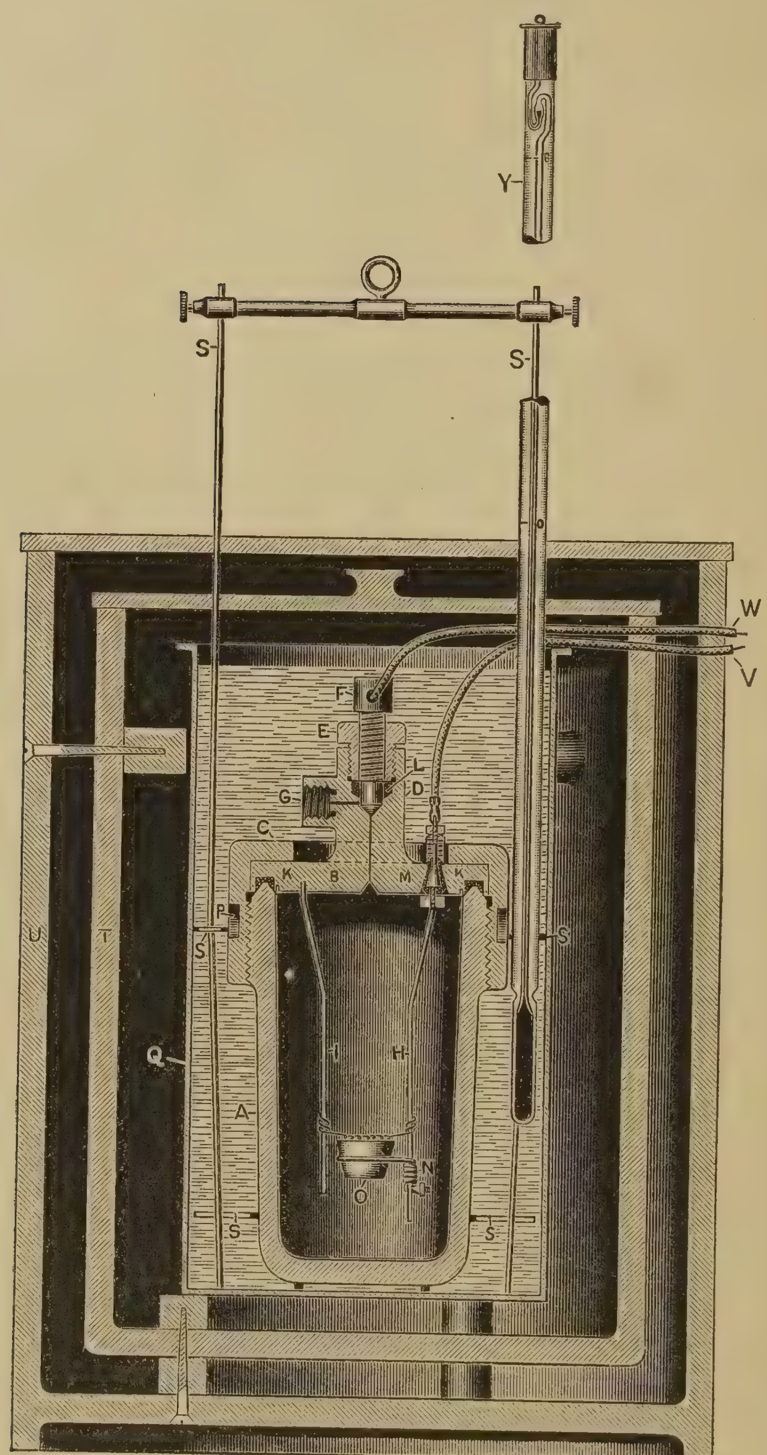

FIG. 4. — BOMB CALORIMETER; APPARATUS AS USED FOR ACTUAL DETERMINATIONS OF HEATS OF COMBUSTION.

as to leave air spaces of about 2½ cm. between the two pails and between the inner and the calorimeter cylinder. The covers are provided with holes for the two arms of the stirrer

and for the thermometer. The covers and the thermometer are held in place by specially devised clamps fastened to the pails. The current for igniting the iron wire over the substance to be burned in the capsule (O) is conveyed by the rubber covered wires, of which one is connected with the valve screw of the bomb and the other with the insulated platinum wire (H) which passes through the cover. The thermometers used for determining the temperature are of special construction and graduated to one-hundredth of a degree, and capable of being read to thousandths by use of a magnifying glass. Those here used were made by Fuess, and calibrated at the Physikalisch-technische Reichsanstalt in Berlin. A hook on the top bar of the stirrer holds a watch for time readings conveniently near the thermometer.

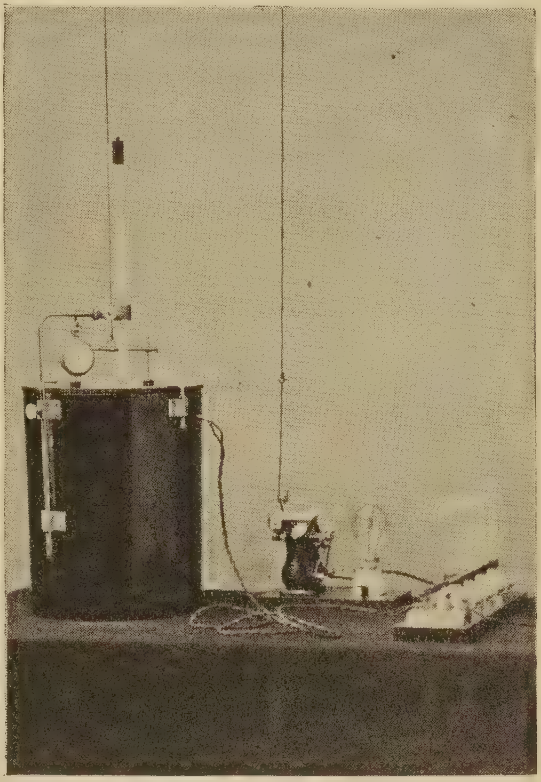

FIG. 5.—BOMB CALORIMETER READY FOR A COMBUSTION.

ACCESSORY APPARATUS.

Apparatus for moving stirrer and for igniting the charge for combustion.—The most convenient source of power for raising and lowering the stirrer we have found to be the direct or alternating current of the city electrical circuit with suitable motors. The same current serves to ignite the charge. As yet no perfectly satisfactory substitute for these currents has been found. Six cells of the Edison-Lalande batteries have most nearly filled the requirements. In Fig. 5 a small motor is shown connected in series with a 16-candle power 110-volt lamp. This style of motor is better adapted for a 55-volt circuit, using a 55-volt lamp in place of the 110. A one-twelfth H. P. high resistance motor is generally used for 110 volts, as it is more durable.

By means of a worm gear fastened directly to the armature shaft the speed is reduced, a final regulation being made, if necessary, by a rheostat until the speed is such as to cause the stirrer to rise and fall about forty times per minute. The connection between the motor and the stirrer is effected by means of a cord which is connected with the motor crank, passes upward to the ceiling or a shelf, over two pulleys, and thence down to the stirrer, as Fig. 4 indicates, although the pulleys are not shown. The cord permits the placing of the motor at a distance if desired.

To raise the fine iron wire to incandescence and thereby ignite the substance, requires a current of three to four amperes. If a 110-volt current is available the necessary current may be obtained by switching it through four 32-candle power 110-volt lamps in parallel, as is shown in Fig. 5. In case a 55-volt current is used the 110-volt 32-c. p. lamps would be replaced by a similar number of 16-c. p. 55-volt lamps. The use of lamps for resistance possesses the advantage that they are lighted for an instant during the heating of the wire and thus enable the operator to determine the time required for its fusion.

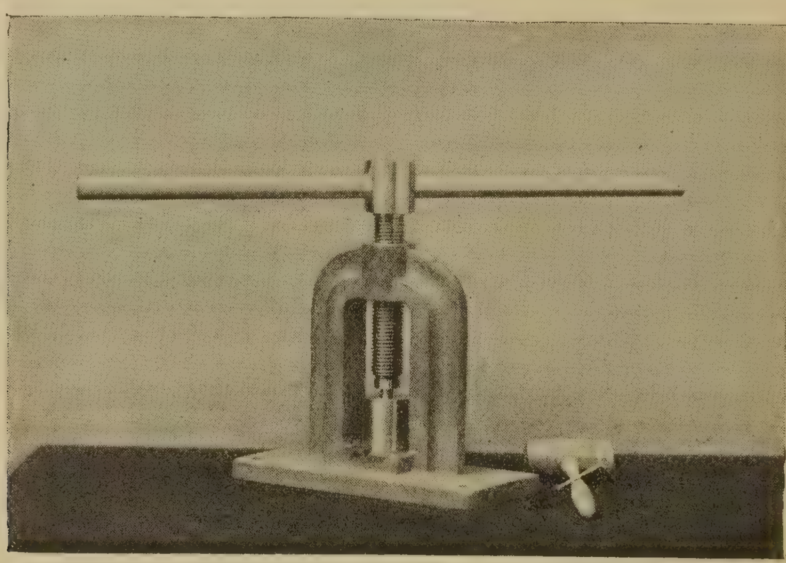

FIG. 6.—PELLET PRESS.

Pellet press and mould.—The material to be burned is generally pressed into a small pellet, so that it will easily be held in the small platinum capsule within the bomb. This pellet form is advantageous also in insuring the complete combustion of all the material which, were it loose in the capsule, might

easily be blown out and escape combustion. The pellet press and mould are shown in Fig. 6. The press is so constructed that a pressure of 50 pounds (22½ kilos), applied at the extremities of the screw arm gives a pressure of over 10 tons (9,100 kilos) on the pellet pin. In practice such a pressure is rarely needed.

The mould consists of three parts: a cylindrical block of steel with a standard half-inch bore; a cylindrical pellet pin of the same size serving as piston; and a cylindrical disk which, like the pellet pin, fits the bore so tightly that when the finely powdered material is held inside the mould between the two, and the pressure applied to compress it into a hard cylindrical pellet, none can be forced in between the pin or disk and the mould. To remove the pellet the top of the pin is rapped with a mallet. The disk falls out first and the pellet follows. The pellets of some substances as cane sugar are friable and easily shattered by the blows of the mallet. To remove these the mould is supported on two pieces of hard wood in the press, and the pin is gently forced down by turning the screw so that the steel disk is forced out and the pellet follows intact.

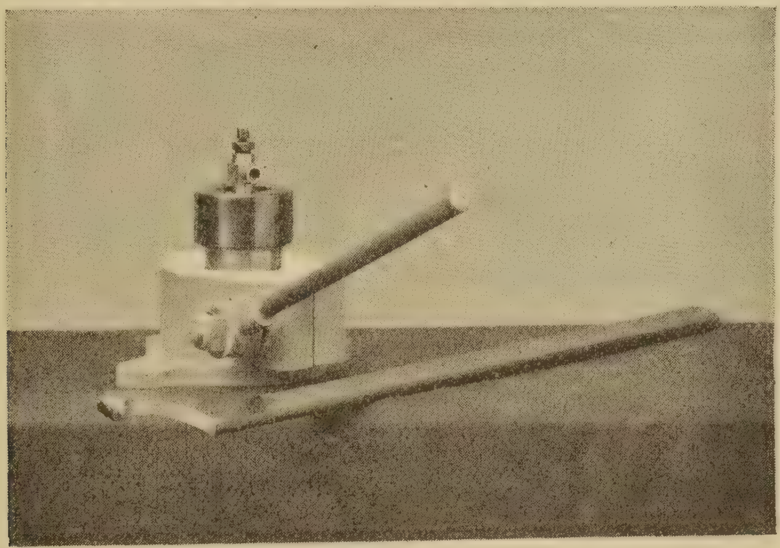

FIG. 7.—CLAMP AND SPANNER.

Clamp and spanner.—Considerable difficulty has been found in holding the bomb securely while the cover is being screwed down. The external surface of the bomb cylinder is smooth and polished and gives very little opportunity for a tight grip. The form of clamp or vise shown in Fig. 7 was devised for the purpose and has proven very efficient.

One jaw of the vise is cast in the same piece as the base, which is securely bolted to a bench or table. The movable jaw is hinged at the back and is drawn together through a maximum distance of about .5 cm. by a lever with a very coarse half thread. A nut with a set screw provides for coarse regulation of the jaws. The jaws are lined with rather thin sheet lead. The nearly cylindrical but slightly tapering space between the jaws closes tightly around the bomb cylinder. The lead lining insures a very close fit and tight grip on the smooth surface of the bomb and prevents it being scratched. When the bomb is held thus in clamps there is no difficulty in securing the collar tightly by use of a spanner about one meter long, which is seen in the foreground of Fig. 7.

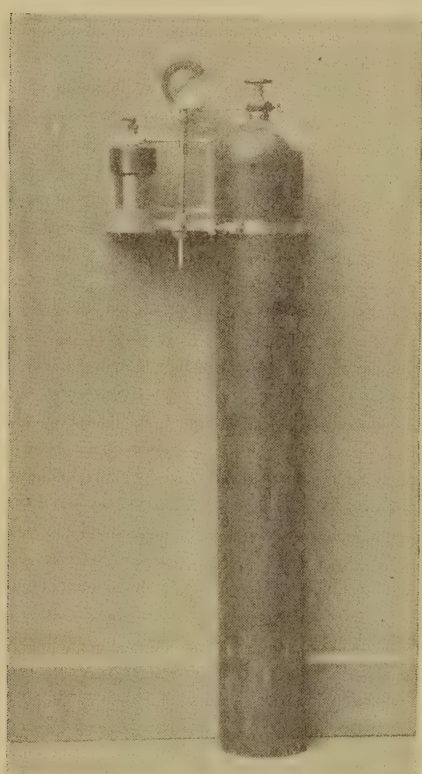

FIG. 8.—APPLIANCES FOR FILLING THE BOMB.

Bomb support, manometer, and couplings for filling bomb with oxygen from oxygen holder.—The oxygen here used is furnished by The S. S. White Dental Mfg. Co. of New York, in cylinders about 125 cm. long and 18 cm. in diameter. By filling at a pressure of 3,000 lbs. per square inch, 100 cubic feet of the gas are forced into the cylinders, an amount sufficient for a large number of determinations. Fig. 8 shows the appliances for filling the bomb. A cast-iron shelf fixed at a convenient height is provided with a socket in which the bomb rests; a hole in which a manometer support is held in place by a set screw; and a steel strap with thumb screw to hold the oxygen cylinder. Coupling tubes connect the bomb, manometer, and cylinder. A valve on the cylinder opens or closes the connection between the latter and the manometer. In like manner a valve on the bomb cover (Fig. 1) regulates the connection between the bomb and the manometer. By slightly opening the bomb valve and then gradually opening the valve on the oxygen cylinder, the gas is allowed to slowly

fill the bomb until the manometer indicates a pressure of twenty atmospheres. The oxygen is then cut off and the bomb valve closed. The operation is extremely simple and rapid. In recent tests of the bomb valve, manometer coupling, and connections, a pressure of 33 atmospheres was left on for thirty-six hours without the slightest indications of a leak.

The graduations of the manometer enable the operator to ascertain when the supply of gas is nearly exhausted. When the pressure falls to thirty or twenty-five atmospheres another cylinder of oxygen is ordered.

It is expected that a later article will discuss methods for determining the hydrothermal equivalent, describe methods of manipulation which experience has indicated as desirable, and give the results obtained in the combustion of various materials. It is also hoped that there may be opportunity to answer questions received from any sources regarding the use of the apparatus for determining the heats of combustion of fuel materials, as coal and gas.

Meanwhile it may be proper to say that the apparatus has proven very satisfactory in the hands of a considerable number of chemists in different parts of the United States. Nearly all of the determinations of the heats of combustion of food materials, with which we are familiar as lately published in this country, have been made by the use of this apparatus.

A RESPIRATION CALORIMETER AND EXPERIMENTS ON THE CONSERVATION OF ENERGY IN THE HUMAN BODY.

BY W. O. ATWATER AND E. B. ROSA.

INTRODUCTION. PURPOSE OF THE INQUIRY.

In previous Reports of the Station reference has been made to the development of an apparatus for measuring the income and outgo of the animal body.* An article entitled "Investigations on Metabolism in the Human Organism" in the Report of the Station for 1896 gave a preliminary account of the experiments made in this direction. The apparatus has been designated as a respiration calorimeter. Its purpose is to study, among other things, the application of the laws of the conservation of matter and the conservation of energy in the animal organism. Viewed from the more practical standpoint the object is to get more accurate information than we now have regarding the fundamental laws of animal nutrition, uses of food in the body, the nutritive values of food materials and the ways of fitting our food to the demands of health, work and purse.

The experiments described in the Report for 1896 had to do with the income and outgo of the body, as expressed in terms

*In the year 1892 the first steps were taken at Wesleyan University toward the development of a respiration calorimeter. The investigation was conducted under the auspices of the University and in connection with the Storrs Experiment Station. The progress of the work led to constantly increasing hopes of success, but at the same time showed more and more clearly the need of considerable amounts of labor and money in order to insure results at all commensurate with the importance of the inquiry. In 1894 provision was made by Act of Congress for an inquiry into the food and nutrition of the people of the United States. The responsibility for the inquiry was vested in the Secretary of Agriculture by whom it was assigned to the Director of the Office of Experiment Stations and the immediate charge was placed in the hands of the Director of the Storrs Experiment Station as Special Agent of the Department of Agriculture. It was considered that a research not only germane but fundamental to such an inquiry might be appropriately aided from this fund, though the amount which could be utilized for the purpose was small. In 1895 the Legislature of Connecticut provided a special annual appropriation to be expended by the Storrs Experiment Station for food inquiries. The resources of the Station for this purpose were thus increased, and with the supplement from the general Government and with the aid from Wesleyan University and other sources it has been possible to greatly enlarge the scope of this especial investigation and prosecute the work in a manner which would otherwise have been entirely out of the question. The inquiry naturally divided itself into two parts. These have to do respectively with the metabolism of matter, and with the metabolism and conservation of energy. That part of the inquiry which has to do specifically with the establishment of the law of the conservation of energy was, in the first instance, undertaken jointly by Messrs. Atwater and Rosa and the present article is accordingly published under their authorship. It is expected that in later articles describing other experiments and phases of the work other gentlemen, who have shared in the investigations, will likewise share in the published authorship.

of chemical elements and compounds. Men engaged either in active work or at rest received certain amounts of food and drink daily. The elements and compounds of the food and drink together with the oxygen which they used from the inhaled air constitute the bodily income. The excreta, solid, liquid and gaseous, including the carbon dioxide and water exhaled, constitute the outgo. Comparison of the income and outgo showed how much of each of the different elements and compounds whose quantities were determined were used by the men for the support of their bodies and for the work which they performed.

In the description of these experiments it was explained that in order to learn satisfactorily just what ingredients of the food the body uses to build up its several parts and keep them in repair, to make muscular tissue, fat and other materials, and to supply the needs of the body for the different kinds of work it has to do, experiments were needed in which the income and outgo of energy, as well as matter, should be determined. To put the statement in another way, if we are going to learn just how the body uses the different materials by which it is nourished, just what are the values of different kinds of food for nourishment, and just what kinds and amounts are appropriate for the needs of people of different classes and with different occupations, we must be able to compare exactly the income and outgo of both matter and energy. The experiments described in the Report for 1896 above referred to, gave a balance of income and outgo of matter. Those here described show the balance of both matter and energy.* The purpose of this article is to describe in brief outline so much of the apparatus and methods as have to do especially with the income and outgo of energy, and so much of the later experiments as bear upon this phase of the subject.

* A detailed description of the apparatus and the experiments made with it would be far to voluminous for the present Report. Such a description is reserved for publication by the U. S. Department of Agriculture through the Office of Experiment Stations, in coöperation with which the apparatus has been developed and the experiments are being prosecuted. Inasmuch as this Report falls into the hands of many who are not specialists in physiological chemistry it is thought proper to give here a less technical explanation of the apparatus, methods and some of the results of the experiments.

The experiments referred to as described briefly in the Report of the Station for 1896, have been reported in more detail in Bulletin 44 of the Office of Experiment Stations of the U. S. Department of Agriculture, entitled "Report of Preliminary Investigations on the Metabolism of Nitrogen and Carbon in the Human Organism, with a Respiration Calorimeter of Special Construction," by W. O. Atwater, C. D. Woods and F. G. Benedict.

The energy of the income is the potential energy of the compounds of the food and drink. The energy of the outgo is of two kinds; the potential energy of the incompletely oxidized materials excreted, especially by the intestines and kidneys, and the kinetic energy given off from the body in the forms of heat and external muscular work. This leaves out of account other possible forms of energy which may be given off from the body. If there be such we have at present no exact knowledge as to their nature or how they may be detected and measured. It is conceivable, for instance, that mental activity may involve the transformation of potential energy into some hitherto unknown form of kinetic energy and that future experimenting with refinement of apparatus and methods may indicate the existence of such metabolism of energy and explain its character and amount. But for the present we must be content to deal with the kinds of energy we are familiar with, and our first task is to measure these as accurately as may be.

The apparatus here described is intended and has thus far been used for experiments with men. There were several reasons for beginning with men rather than with domestic animals. The study of human nutrition is very important. In the earlier development of the work, when many difficulties were to be overcome, it was very desirable to have an intelligent person inside the apparatus rather than an animal whose movements could not be controlled. Indeed the most advantageous way to develop methods and apparatus for experiments with animals was through such preliminary experience with men. The results of the experience thus far gained are now being utilized in planning for apparatus to be used with small animals, as sheep and dogs. If this effort shall prove successful, as we have every reason to hope it may, the next step will be to devise apparatus and methods for experiments with larger animals, as horses, oxen and cows.

It is to be remembered also that the fundamental laws of nutrition are the same for domestic animals as for man and that better knowledge of these laws is pressingly needed as the foundation for proper understanding of the practical problems which the farmer has to do with in the feeding of his stock. A great deal of the experimenting which is now being

carried out fails to fulfill its best purpose because these fundamental principles are not yet understood. The most experienced investigators are fully persuaded that the best service which can be rendered to agriculture in this direction, for some time to come, must be in abstract experimental inquiries of the class to which these belong.

THE APPARATUS.

The name here used for the apparatus, "respiration calorimeter," is suggested by the fact that it is essentially a respiration apparatus with appliances for calorimetric measurements. As a respiration apparatus it is similar in principle to that of Pettenkofer. The calorimeter is essentially a water calorimeter, that is to say, the heat evolved in the chamber is measured by a current of water. The appliances for measurement of both the respiratory products and the heat given off from the body differ in some important respects from those of any other apparatus with which we are familiar.

The apparatus includes, first of all, a room or chamber in which the subject remains during the experiment. The chamber is furnished with a folding chair and table for the man's use during the day, and a folding bed on which he sleeps at night. When the experiments involve muscular work a stationary bicycle, especially arranged for measuring the work done, is also introduced. Light enters through a window so that the occupant can see to read and write. Ventilation is provided by a current of fresh air, maintained by a pump specially devised for the purpose. This pump not only keeps up a constant current of air, but also measures its volume and withdraws samples regularly and accurately for analysis. The air is made to enter the chamber at the same temperature as when it goes out, so that the quantities of heat brought in and carried out by this ventilating current are the same. Arrangements are provided for passing food and drink into the chamber and for removing the solid and liquid excreta. Arrangements described beyond prevent the passage of heat through the walls of the apparatus. The heat given off from the body is carried away by a current of cold water which passes through a series of pipes inside the chamber. Houses are warmed in winter by a current of water which is heated in the basement of the house, and passes through pipes and radiators in the different rooms. The heat thus radiated from the water into the room keeps the air of the latter at the desired temperature. In like manner the house might be cooled in summer by a current of cold water. In this case the radiators would become absorbers. The heat would be taken up from the air of the room by the cold water and carried away. Exactly this is done by the absorbers inside the chamber of the respiration calorimeter. By regulating the temperature of this water current as it enters, and also its rate of flow, it is possible to carry away the heat just as fast as it is generated, and thus maintain a constant temperature inside the chamber. The amount of the outgoing water and its temperature are measured, thus determining the heat carried away.

Inasmuch as the technical details of the apparatus and methods are to be given elsewhere a brief account will suffice here. This may include a few words regarding the arrangements for measuring the temperature of the air inside the

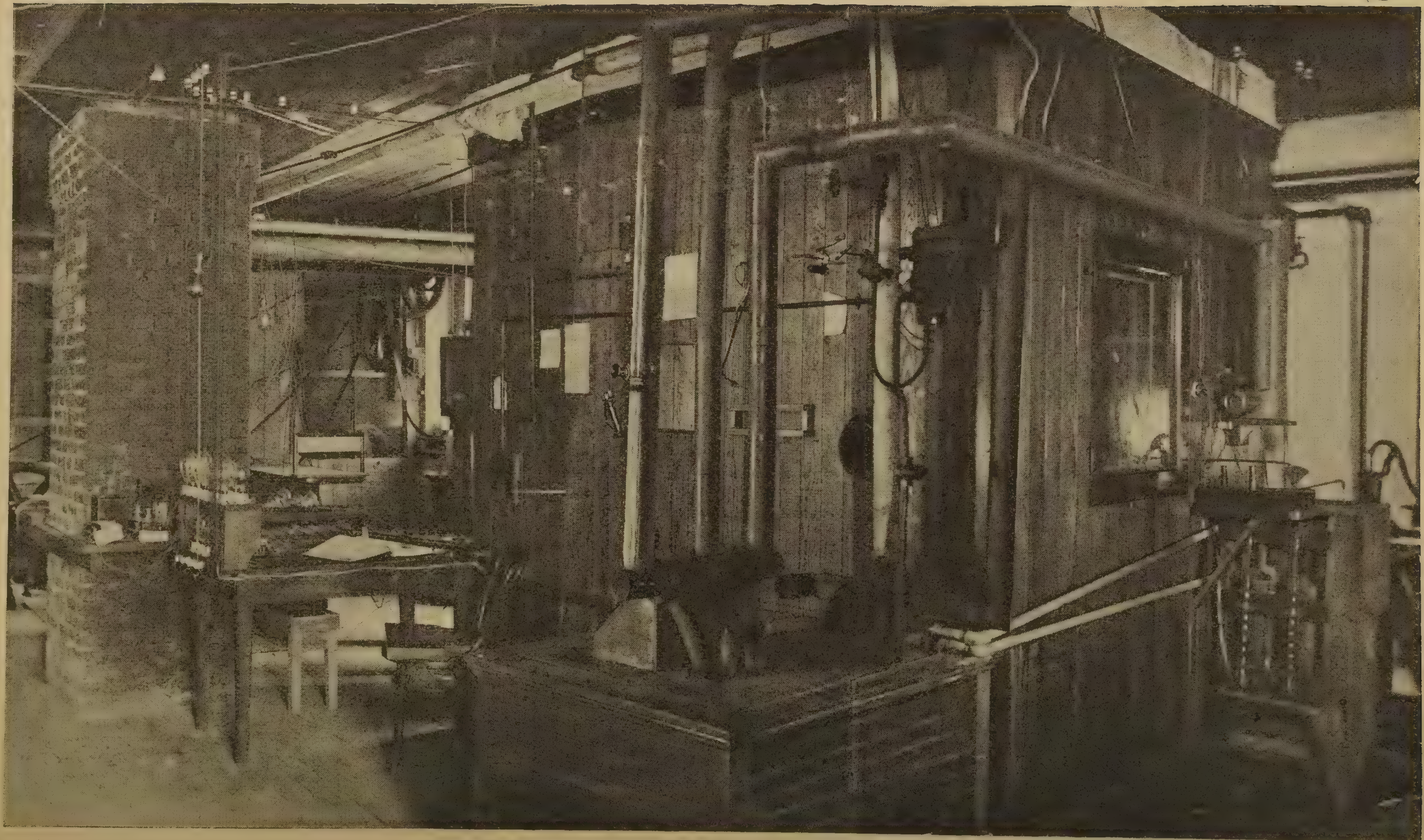

Fig. 9.—Respiration Calorimeter. General View.

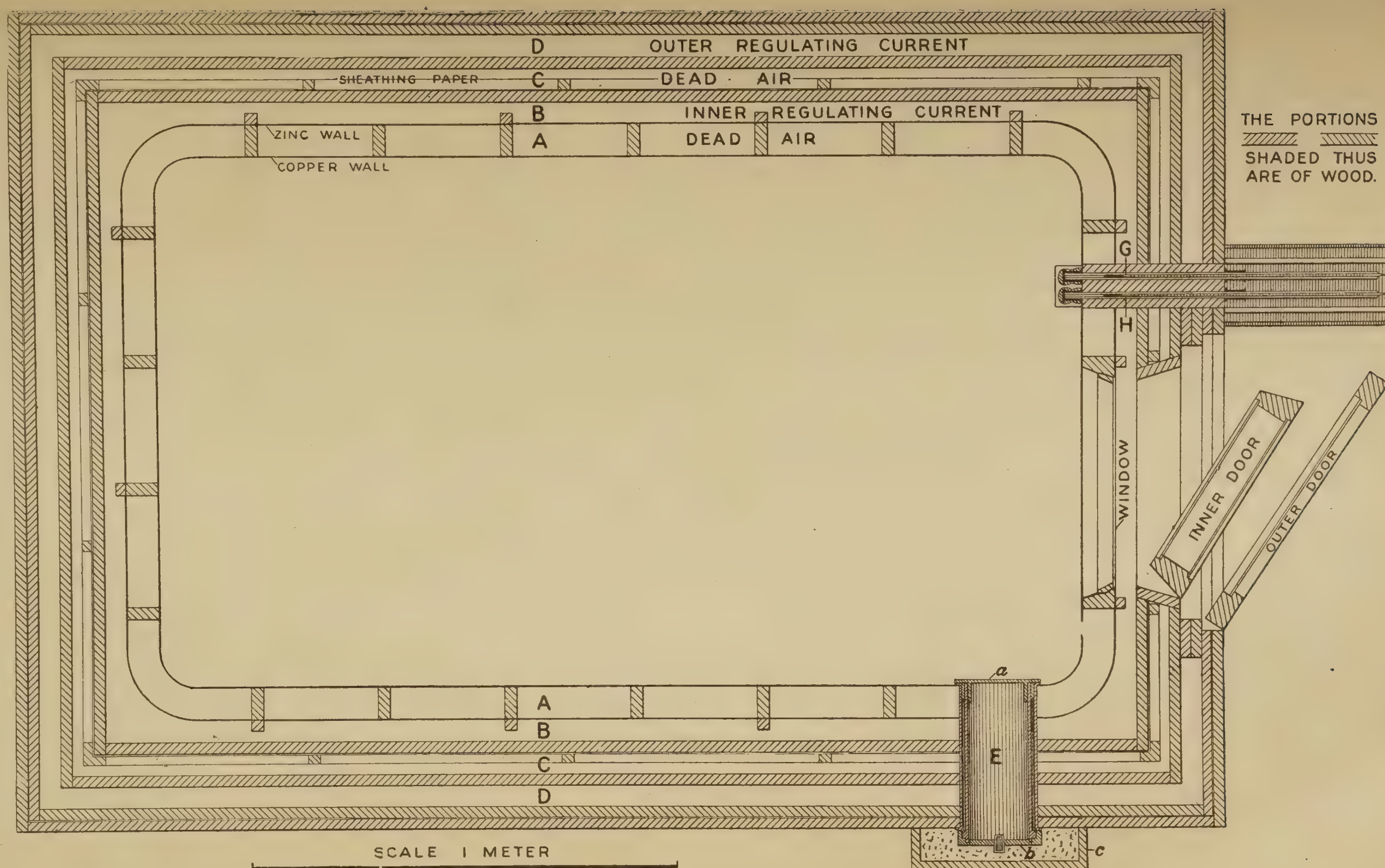

FIG. 10.—HORIZONTAL CROSS-SECTION OF RESPIRATION CALORIMETER.

chamber, for regulating the temperature of the ingoing air, for preventing the passage of heat through the walls of the apparatus, and for measuring the quantities of heat given off by the body and carried out by the water current.

If to these is added a very brief account of the methods for measuring the volume of the ventilating air current, and for determining the composition before and after it has passed through the chamber, little more need here be said regarding the apparatus and methods of its use.

A general idea of the apparatus can be had from figures 9 and 10. Figure 9, from a photograph, is a general view of the principal parts of the apparatus, though the pump and aspirators used for moving, measuring and sampling the ventilating air current, and the refrigerating machine are not shown. In the center is the large chamber which is surrounded by sheathing of wood. At the end of the chamber, on the right, is shown a glass door which serves also as a window. In the foreground, near the center and at the right, are the pipes through which the ventilating current of air passes. At the right of the window and just below it are the arrangements for cooling and for measuring the current of water which brings away the heat from the interior of the chamber. At the left, in front of the large brick pillar, is a table at which an observer sits to record the temperature of the interior of the apparatus and of the currents of air and water, these temperatures being measured by electrical thermometers. Behind the brick pillar is the refrigerating machine, not shown in the picture. The object of this is to cool the brine, *i. e.*, a solution of calcium chloride contained in a large tank in the center foreground. The tank is surrounded by a wooden casing. The ventilating current of air, before it enters the chamber, is passed through copper cylinders which are immersed in brine in this tank, and thus cooled to a temperature of from —19 to —22 degrees Centigrade, or from —2 to —8 degrees Fahrenheit. At this very low temperature nearly all of the water is removed from the air, so that it enters the chamber quite dry. Just before entering, at the right of the glass door, it is warmed to the temperature of the interior of the chamber. On coming out it passes once more through copper cylinders in the cold brine, and thus the larger part of the water which has been imparted to it by the respiration of the man inside the chamber is frozen and removed. The air pump is at the right and the aspirators are at the left of the position occupied by the camera in taking the photograph.

THE RESPIRATION CHAMBER.

The internal construction of the chamber and the arrangements for regulating the temperature are shown in horizontal section in figure 10.

The chamber proper is practically an apartment with double walls of metal, the inner wall being of sheet copper and the outer one of zinc. The interior is 2.15 m. (7 ft.) long, 1.92 m. (6 ft. 4 in.) high, and 1.22 m. (4 ft.) wide, the corners being rounded. It thus has a little less than 28 square feet of floor space. The cubic content is not far from 4.8 cubic meters or 175 cubic feet. The inner wall is made of large sheets of copper, the seams being soldered so that when the windows and other openings are closed the chamber is air tight, and the only air which enters or leaves is that of the ventilating current. Outside this copper wall is one of zinc. Between the two metal walls is an air space (A) of 7.5 cm. (3 in.). In this space stands a wooden frame work to

which the two metal walls are securely attached. This metal chamber is the calorimeter proper. In order to protect it from the fluctuations of temperature of the room in which it stands, it is enclosed within three concentric walls of wood. Between the zinc and the innermost wooden wall is an air space (B) of 5 cm. (2 in.), between this wall and the next is a third air space (C) of 5 cm., and finally between this and the outer wall is a fourth air space (D), likewise of 5 cm. The wooden walls are made of matched pine covered with sheathing paper. The outer one is double with sheathing paper between. The air in the spaces A and C is "dead air," while that in the spaces B and D can be kept in constant circulation by means of rotary fans in boxes outside. Each of the spaces B and D is continuous around the sides and over the top and bottom of the calorimeter, and each communicates with its fan box by means of one passage extending from the top of the air space to the top of its fan box, and another from the bottom of the air space to the bottom of the fan box. We may thus look upon these air spaces as shields guarding the interior space occupied by the calorimeter from changes in temperature without. They thus render necessary aid in accomplishing a fundamental object, namely, the keeping of the temperature of the air in the space B the same as that of the interior of the chamber. When these temperatures are the same there will be no passage of heat through the walls, either into or out of the chamber.

The outer air current (D) is used for the coarser regulations of temperature. In the middle of the dead air space (C) is a wall of sheathing paper intended to more effectually prevent the external temperature from affecting that of the calorimeter.

The walls are provided at the right with glass doors or windows. At E in figure 10 is a cylinder of copper which passes through the walls of the chamber and also through the encasing walls of wood. This cylinder, which is 15 cm. (6 in.) in diameter, serves for passing food and other materials into and out of the calorimeter chamber, and is here called the "food aperture." It is closed at the ends by caps *a* and *b*. The outer cap *(b)* is screwed tightly to the cylinder so as to make an air-tight closure. Outside of this is a box or cover *(c)*, made of wood and filled with cotton or other non-conducting material, the purpose being to prevent the passage of heat through E.

Measurements of temperature.—The measurements of temperature are made in part by mercury thermometers, but mainly by electrical methods. The electrical measurements of temperature are made by use of either the German silver-iron thermal junctions or by resistance coils of fine copper wire. Provision is made for connecting these with a D'Arsonval galvanometer especially constructed for the purpose by Mr. O. S. Blakeslee, Mechanician of Wesleyan University. The electrical thermometers permit measurements of one-hundredth of a degree Centigrade or less.

Temperature of air inside the chamber.—Inasmuch as the temperature of the air is not the same in different parts of the chamber, and it is desirable to know the average or resultant temperature of the whole, the attempt is made to learn the latter by the use of a series of five electrical thermometers at places near the sides, top, and bottom. These consist of resistance coils of copper wire connected with a slide-wire Wheatstone bridge and the galvanometer outside. The

measurements are so delicate that even slight movements of the person inside, such as rising from the chair, reveal themselves to the observer outside by the immediate rise in the thermometric reading.

Regulation of temperature of ingoing air.—In order that the ventilating current of air shall not carry out of the chamber any more or any less heat than it brings in, the temperature must be the same when it enters as when it leaves. Accordingly the incoming air, which leaves the brine tank at a very low temperature, is warmed, before its entrance to the chamber, to the temperature of the outgoing air. The devices for this purpose are such that the difference of temperature of the incoming and outgoing currents can be kept inside of .01 degree C. In actual experiments the positive and negative differences are made to counterbalance each other.

Arrangements for preventing the passage of heat through the walls of the calorimeter.—The difference between the temperature of the copper wall and that of the zinc is measured by a system of thermo-electric junctions, in 304 pairs, distributed over the sides, top and bottom, one-half of the junctions (iron-German silver) being in close thermal contact with the copper wall and the other half, (German silver-iron) with the zinc wall. The difference of temperature of the two walls is made as small as possible by warming or cooling the air in the space B, and the positive and negative differences are made to counterbalance each other. Thus the corresponding movements of small quantities of heat inward and outward also counterbalance, and the chamber neither gains nor loses heat through the walls.

For the measurement of differences of temperature, as well as for the warming and cooling, the walls of the calorimeter are considered as divided into four sections, viz.:—(1) the top; (2) the upper half of the sides or "upper zone"; (3) the lower half of the sides or "lower zone"; (4) the bottom. The systems of thermo-electric elements for heat measurements, of wires for warming and of water pipes for cooling, are each divided into corresponding sections.

The observer's table.—This is shown in figure 9 at the left, in front of the brick pier. A shelf fastened to the pier and shown on the right of the latter, behind the table in the picture, holds the galvanometer and scale. The scale is seen in the picture at the front end of the shelf over the table. The galvanometer is at the other end of the shelf, two meters from the scale and obscured by the pier. On the table are the switches to bring the various circuits into connection with the galvanometer, and with them the Wheatstone bridges, and the banks of electric lamps for varying the heating currents. At the front of the table near the chair is the record book for noting the observations, which are very numerous. Plans are being made to move the table to the end of the chamber near the door.

With the aid of the devices thus briefly described an experienced operator at the observer's table can easily control the temperature of B and make it follow the variations of the interior of the chamber very closely. When the rate of generation of the heat in the chamber is reasonably uniform and the temperature is nearly constant, the deflection of the image on the scale at the observer's table can usually be kept within one division of the scale, which means an average difference of temperature between the copper and zinc walls of less than

.01 of a degree C. In ordinary experiments the difference is generally kept within this limit and seldom reaches .05 degrees. The differences are both positive and negative and are easily made to counterbalance each other during shorter periods and during the whole experiment.

Measurement of the heat carried out by the water current.—The principle here employed is simple. The chamber neither gains nor loses heat by the air current nor through the walls. The current of cold water which passes through the heat absorbers inside the chamber is caused to enter at a temperature generally but little above the freezing point, and to flow out at such a rate as to absorb and carry off the heat just as fast as it is generated inside the apparatus. The temperature of the water is measured as it enters and as it comes out. The mercury thermometers are shown at G and H in figure 10. The electrical thermometer indicates the difference of temperature between the incoming and outgoing water currents by the difference of resistance of two coils of thin copper wire, of which one is in each pipe at the place of entrance or exit from the calorimeter. The difference is measured by a Wheatstone's bridge on the observer's table. The mass of water is measured automatically by the apparatus shown below and at the right of the window of the respiration chamber in figure 9.

From the mass of the water which has passed through the absorber in a given time, and the rise in temperature, the quantities of heat brought out are readily calculated. To this is to be added a certain amount of heat which is carried away with the water vapor produced in the apparatus. This is practically the difference between the water vapor in the incoming and outgoing air. From the amount of this vapor, and its latent heat at the temperature of exit, the amount of heat it carries out is easily computed.

Meter pump for regulating, measuring and sampling the ventilating air current.—Three forms of apparatus have been used for maintaining the air current and measuring its volume. One consisted of an ordinary air pump with a meter made by Elster in Berlin.* With this we have been unable to make measurements as accurate as seem to us desirable.

For taking samples of air for analysis, aspirators of 150 liters capacity were employed at the outset and are still used. The measurements with these have been found quite accurate.† The most satisfactory arrangement we have found, and one which serves the threefold purpose of maintaining the air current, measuring its volume and delivering aliquot samples of convenient size for analyses, is an apparatus designed and made by Mr. O. S. Blakeslee, and appropriately designated by him as a "meter-pump." This is shown in figure 11. The essential parts for maintaining the air current and measuring its volume are cylinders of steel. There are two pumps which work in unison. Three steel cylinders are employed for each pump. The inner and outer cylinders are arranged concentrically with an annular space 1.2 cm. in width between them. This space is partly filled with mercury. Between the inner and outer cylinders, which are stationary, plays a central cylinder, its lower portion being immersed in the mercury. The central cylinder is closed at the top and is raised and

* See Report of the Storrs Station, 1896, p. 91, and Bulletin 44 of the Office of Experiment Stations of the U. S. Department of Agriculture, p. 19.

† See description in the Report and Bulletin just named.

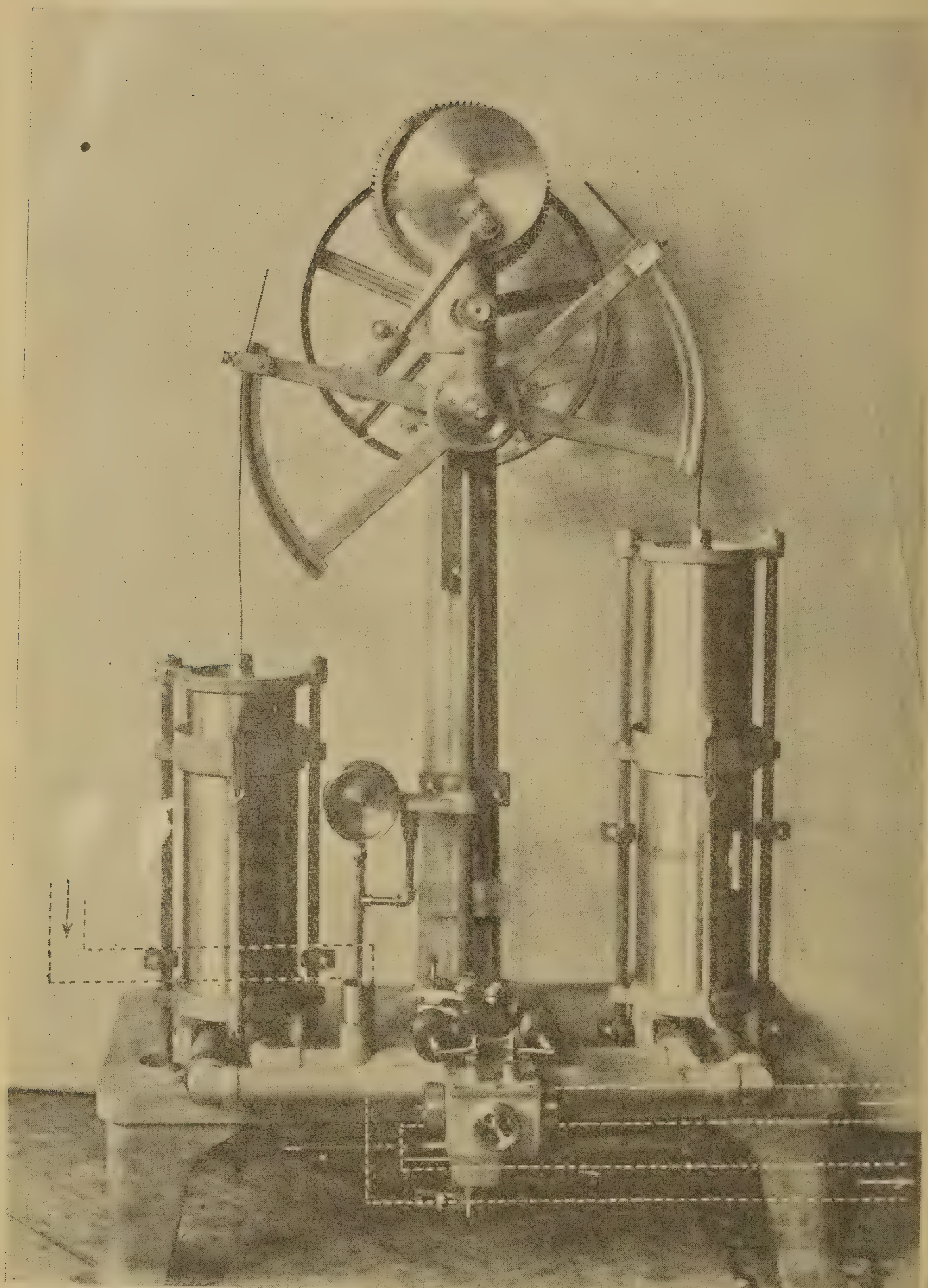

FIG. 11.—BLAKESLEE METER-PUMP.

lowered by a walking beam. The inner cylinder is also covered at the top, but through this cover are two circular apertures opened and closed alternately by an automatic valve, actuated by a compressed air mechanism underneath. Connected with these apertures are pipes passing downwards through the inner cylinder. One serves to convey the air, as it comes from the chamber, into the pump as the central cylinder rises. As the cylinder falls the other pipe conveys the air outward and thus plays the part of a discharge pipe. The automatic valves open and close the inlets and discharge pipes so that with each stroke of the inner cylinder the air is cut off at the proper time. The length of the stroke of the cylinder is determined exactly by rods, provided with stops, these rods playing through guides on two sides of each cylinder, and by this arrangement the only variation is that which comes with the very slight changes in the length of the rods due to changes of temperature. The air coming from the discharge pipe, escapes into the room, but by a special device the air of each fiftieth stroke of each pump is diverted into a receptacle, from which it is being constantly drawn for analysis. The dotted lines in the picture indicate the position of the pipes through which the air passes into and out of the pump. The details of this apparatus will be more appropriately described in another place. It will suffice to say here that the results obtained from its use are very satisfactory.

Cooling apparatus.—It is desirable that the ventilating current of air shall enter the respiration chamber as dry as possible. To this end it is cooled to a temperature of —19 to —22 degrees C. (—2 to —8 degrees F.), by passing through copper cylinders which are immersed in brine in the tank shown in figure 9. The brine is cooled by use of an ammonia refrigerating apparatus.* The air after passing out of the cylinder is warmed before entering the chamber in the way described. On coming out of the chamber the air current is again passed through copper cylinders immersed in the brine, and thus practically all of the water which has been imparted to it within the chamber is removed. The same brine is used for cooling the current of water which passes through the absorbers and conveys away the heat from the chamber.

Analyses of air, determinations of carbon dioxide and water.—The methods used for these purposes are essentially the same as described in the Report of Storrs Experiment Station and Bulletin 44 of the Office of Experiment Stations of the U. S. Department of Agriculture above referred to. It will therefore suffice to say here that the larger part of the water is caught in the copper cylinders, immersed in the cooling brine as above described, and its amount found by weighing. The residue of the water of both the incoming and outgoing air current is determined in samples by passing through U tubes containing pumice stone and sulphuric acid. The carbonic acid is in like manner determined by passing through U tubes containing soda lime.

In the ordinary experiments the determinations of water, carbonic acid and heat are made for periods of six hours.

* See description of the arrangements for cooling in Report of the Storrs Experiment Station for 1896, p. 92, and Bulletin 44 of the Office of Experiment Stations of the U. S. Department of Agriculture, p. 22.

TESTS OF THE ACCURACY OF THE APPARATUS.

The accuracy of the measurements of heat and of carbon dioxide and water has been tested by two methods. In one the heat determinations were tested electrically. In the other the determinations of heat, water and carbonic acid were tested by burning alcohol inside the calorimeter chamber.

The electrical tests of the heat measurements.—For this purpose a wire resistance coil was placed inside the chamber. This was connected with wires passing through the wall to the outside and connected with a voltmeter and an ammeter and, in some instances, a Thompson balance. The amount of heat given off inside the apparatus was calculated from the current and was also determined in the water passing through the absorbers. The details of the arrangements and observations are reserved for future publication. The final results are given in table 49.

TABLE 49.

Summary of electrical test experiments.

DATE.	Duration, Hours and Minutes.	Heat as Measured.	Capacity Correction.	Corrected Heat.	Theoretical Heat.	Per Cent. Measured.
	H. M.	Calories.	Cal.	Cal.	Cal.	
March 20, 1897, - -	13–20	1001.9	−9.0	992.9	989.5	100.3
March 25, 1897, - -	6–05	528.8	−6.0	522.8	522.1	100.1
March 26, 1897, - -	7–17	1252.1	−1.2	1250.9	1253.1	99.8
April 30, 1897, - -	6–00	21.4	0.0	21.4	21.5	99.5
January 8, 1898, - -	4–00	233.4	−4.0	229.4	230.5	99.6
Total, - - -	—	—	—	3017.4	3016.7	100.0

One objection to this use of the electrical method as a test of the accuracy of the apparatus is found in the fact that the conditions were not the same as obtain in an experiment with a man. There was no ventilating current of air through the apparatus, and no water or carbonic acid was given off within it. The tests which follow were made by burning ethyl alcohol inside the apparatus while the ventilating current was passing through. The devices were such as to insure complete combustion of the alcohol, as shown by somewhat extended experiments to be described elsewhere. The carbonic acid, water and heat were measured in the same way as in an actual

TABLE 50.

Summary of results of alcohol check experiments.

Date.	Duration, Hours and Minutes.	Alcohol Burned.	Carbon Dioxide.			Water.			Heat.		
			Theoretical.	Found.		Theoretical.	Found.		Calculated.	Found.	
	H. M.	Grams.	Grams.	Grams.	%	Grams.	Grams.	%	Calories.	Calories.	%
1897.											
April 27–29,	52–30	955.4	1659.0	1657.7	99.9	1106.4	1109.6	100.3	5449.9	5400.6	99.1
May 10–11,	29–56	798.8	1387.5	1385.5	99.9	924.8	925.6	100.1	4556.6	4568.8	100.3
May 26–27,	33–50	505.4	877.6	882.9	100.6	—	—	—	2882.9	2871.4	99.6
October 27–28,	34–34	799.7	1386.2	1352.6	97.6	—	—	—	4530.2	4542.0	100.3
November 2–3,	35–09	788.2	1366.6	1374.6	98.3	912.4	920.9	100.9	4488.1	4501.3	100.3
December 2,	11–40	245.3	—	—	—	283.8	283.2	99.8	1389.5	1383.8	99.6
1898.											
January 6,	5–50	112.2	193.7	193.3	99.8	129.8	131.3	101.2	635.6	647.3	101.8
January 24–27,	83–44	1607.8	2787.0	2771.0	99.4	1861.3	1884.5	101.2	9153.2	9127.7	99.7
May 9–10,	24–00	503.9	867.9	863.7	99.5	586.6	584.8	99.7	2874.3	2862.0	99.6
Total,	311–13	6316.7	10525.5	10481.3	99.6	5805.1	5839.9	100.6	35960.3	35904.9	99.8

experiment with a man. The theoretical amounts of these substances were also determined from the known composition of alcohol and from actual determinations of the heats of combustion of the latter by use of the bomb calorimeter. The value used for the computations was 7,060 small calories per gram absolute alcohol.

Tests were made by burning quantities of alcohol varying from 112 grams to 1,608 grams during times ranging from 6 to 84 hours. The rate of burning of the alcohol ranged from 15 to 22.5 grams per hour. The observations were made by periods of 6 hours each. Several of the tests were made before the actual experiments with the men. Others alternated with those experiments the purpose being to test the accuracy of the apparatus before and after each experiment. The results of the alcohol check tests are summarized in table 50.

EXPERIMENTS WITH MEN.

The subject of the experiments here described was Mr. E. Osterberg, the laboratory assistant with whom several of the former experiments were made.

The general plan of these experiments is the same as that of the experiments described in the Report of the Storrs Experiment Station and the Bulletin of the Office of Experiment Stations above referred to. For each experiment a diet is selected such as has been found by previous experiments to meet, as nearly as may be, the needs of the person under experiment. For the sake of greater accuracy in sampling and analysis, most of the materials, and especially the meats, are prepared in advance, and are kept in cans after sterilizing by heat when necessary. In the preparation of the meat, generally lean beef, the lean meat is finely chopped, broiled slightly and carefully mixed. Convenient portions of 100 grams or more are then weighed out, canned, sterilized and set aside for use. In putting up the bread for use the crust is removed and the crumb is cut in small pieces and likewise canned. Portions of breakfast cereals, which require no previous cooking but are eaten with milk, are weighed out in advance and put up in air-tight packages. Weighed portions of butter are put in small pomade cups and kept in a cool place. The portions which are weighed out in advance are such as are convenient for each meal.

As fresh milk is generally more palatable than that which has been preserved, portions are obtained each day from a milkman who supplies the milk from a mixed herd. The composition is very nearly uniform, though determinations of fat, nitrogen and total solids are made in each sample. Of the other materials a single analysis, generally in triplicate, suffices. The determinations made are, in general, water, carbon, hydrogen, nitrogen, ether extract, ash and heat of combustion.

Composition of food materials, etc.—The results of the analyses of the food materials and feces are given in table 51 herewith.

TABLE 51.

Composition of food materials, etc.

Laboratory No.	FOOD MATERIALS, ETC.	Experim't No.	Nitrogen.	Carbon.	Hydrogen.	Water.	Protein (N. x 6.25).	Fat.	Carbohydrates.	Ash.	Heats of Combustion per Gram.*
			%	%	%	%	%	%	%	%	Cal.
2789	Beef, fried, - -	6	4.77	19.28	3.03	60.3	29.8	8.7	—	2.09	2.421
2835	Beef, - - -	9	4.10	16.35	2.25	67.3	25.6	5.4	—	1.56	1.928
2788	Ham, deviled, -	6	2.64	36.11	4.91	42.2	16.5	36.9	—	4.03	4.353
2790	Eggs, - - -	6	2.24	14.39	2.19	73.2	14.0	11.3	—	.98	1.928
2793	Butter, - -	6	.16	62.82	10.34	9.3	1.0	87.3	—	2.39	7.954
2833	Butter, - -	9	.19	62.24	9.89	10.2	1.2	84.8	—	3.80	7.761
2799	Milk, - - -	6	.48	8.27	1.22	85.3	3.0	5.4	5.6	.69	.935
2836	Milk, - - -	9	.52	3.85	.60	90.7	3.3	.1	5.2	.78	.393
2803	Bread, white, -	6	1.33	25.45	3.85	43.9	8.3	1.6	45.0	1.24	2.540
2834	Bread, - -	9	1.34	23.15	3.45	44.7	8.4	.2	44.3	2.44	2.400
2830	Br'kfast food, wheat	9	1.58	40.46	5.75	7.5	9.9	1.6	77.7	3.26	4.071
2791	Beans, baked, -	6	1.15	11.85	1.78	71.4	7.2	.4	19.2	1.86	1.222
2831	Br'kfast food, maize	9	1.78	43.86	6.72	5.6	11.1	8.7	71.1	3.46	4.444
2792	Peas, canned, -	6	.05	7.01	1.18	81.4	.3	.2	17.9	.24	.759
2786	Sugar, - - -	6	—	42.10	6.48	—	—	—	100.0	—	3.963
2832	Sugar, - - -	9	—	42.10	6.48	—	—	—	100.0	—	3.960
2829	Ginger snaps, -	9	.96	40.21	5.49	5.3	6.0	9.5	75.6	3.70	4.358
2808	Feces, - - -	6	1.29	10.64	1.56	78.6	8.1	4.1	5.6	3.64	1.194
2838	Feces, - - -	9	1.19	12.13	1.72	72.9	7.4	3.9	11.4	4.40	1.343

* As determined.

Measurement and analysis of excretory products.—The methods of treating these products are essentially the same as in the previous experiments already referred to. The separation of feces was made by use of charcoal, and the analyses and heats of combustion by the same method employed for food materials. The urine is collected for each six hours and its specific gravity,

and the nitrogen, carbon and hydrogen and the heat of combustion of the dried residue are determined. The methods of drying by which transformation of urea into ammonium carbonate and loss of the latter may be avoided or properly allowed for, have been made the subjects of special experimental study, the results of which will be published later.

The heats of combustion of food materials and excretory products are made by use of the bomb calorimeter described in the previous article of this Report.

Daily routine of the experiment.—As above stated each experiment is divided into two periods. In the first or preliminary period, of four days, the analyses of feces and urine are made, the data thus sufficing for a digestion and nitrogen metabolism experiment. On the evening of the fourth day the subject enters the respiration chamber, though the actual respiration calorimeter experiment does not begin until 7 o'clock the morning of the fifth day. The night sojourn in the apparatus suffices to get the temperature of the air in the apparatus and its content of carbonic acid and water into equilibrium so that accurate measurements may begin with the morning of the fifth day and continue until 7 o'clock on the morning of the ninth day, thus making the duration of this experiment exactly four days. The routine of each day is illustrated by the accompanying program which was prepared and used for experiment No. 6. The man weighs himself on a small Fairbanks platform scale, especially made for the purpose and sensitive to 5 grams.

Daily program of metabolism experiment No. 6, May, 1897.

7:00 A. M.—Rise.
Pass urine.
Weigh self, stripped and dressed.
7:45 A. M.—Breakfast.
Weigh self.
8:20 A. M.—Begin work.
10:20 A. M.—Ten minutes' rest.
10:30 A. M.—Weigh self. Drink 200 grams water.
12:30 P. M.—Stop work.
1:00 P. M.—Pass urine.
Weigh self.
1:15 P. M.—Dinner.
Drink 200 grams water.
Weigh self.

1:50 P. M.—Begin work.
3:50 P. M.—Ten minutes' rest.
4:00 P. M.—Weigh self. Drink 200 grams water.
6:00 P. M.—Stop work.
Weigh self.
6:30 P. M.—Supper.
Change underclothing.
Weigh self, stripped and dressed.
7:00 P. M.—Pass urine.
10:00 P. M.—Weigh self. Drink 200 grams water and retire.
1:00 A. M.—Pass urine.

The food.—The daily diet of the two experiments which are here described, and are designated by the current numbers 6 and 9, was as stated herewith. The numbers of the digestion experiments are those given in the article on this subject (page 154).

Daily Menu.—Metabolism experiment No. 6. Digestion experiments Nos. 39 and 40.

BREAKFAST.	Grams.	DINNER.	Grams.	SUPPER.	Grams.
Deviled ham, - -	20	Fried beef, - -	100	Deviled ham, - -	30
Boiled eggs, - -	55	Butter, - - -	30	Butter, - - -	25
Butter, - - -	20	Milk, - - - -	50	Milk, - - -	600
Milk, - - - -	200	Bread, - - -	125	Bread, - - -	175
Bread, - - - -	150	Baked beans, - -	125	Sugar, - - -	15
Sugar, - - - -	15	Sugar, - - -	20	Coffee, -	about 300
Coffee, -	about 300	Coffee, -	about 300		

Daily Menu.—Metabolism experiment No. 9. Digestion experiments Nos. 45 and 46.

BREAKFAST.	Grams.	DINNER.	Grams.	SUPPER.	Grams.
Cooked beef, - -	100	Cooked beef, - -	150	Butter, - - -	15
Butter, - - -	15	Butter, - - -	20	Skimmed milk, -	390
Skimmed milk, - -	160	Skimmed milk, -	210	Bread, - - -	25
Bread, - - - -	25	Bread, - - -	50	Breakfast food, wheat,	75
Breakfast food, maize,	50	Breakf'st food, wheat,	50	Sugar, - - -	30
Sugar, - - - -	25	Sugar, - - -	25	Coffee, -	about 300
Coffee, -	about 300	Coffee, -	about 300		

RESULTS OF THE EXPERIMENTS.

The results of two experiments, Nos. 6 and 9 of the series actually undertaken, may be briefly recapitulated by tables selected from a number which have been prepared to show the full details. The general character of these tables may be illustrated by the following, which belong to experiment No. 6.

In this experiment the subject was engaged in active muscular work. The energy of the external muscular work done was assumed to be entirely transformed into heat within the chamber. The larger part was first transformed into electrical energy by a small dynamo which was belted to the wheel of a stationary bicycle, and was then transformed into heat by an electric lamp through which the current passed. A small portion was transformed into heat by the friction of this bicycle-dynamo or ergostat. The heat thus produced was measured with the heat given off from the body. The muscular work was continued for about eight hours per day, and the external muscular power as roughly measured by this ergostat was estimated to be equivalent to not far from 250 calories per day. This measurement was not as accurate as desirable and a special apparatus is now being constructed for the purpose. In experiment No. 9 the subject was as quiet as he well could be. In the four days of the preliminary period he moved about but little, and engaged in no considerable amount of either muscular or mental labor. During the four days passed in the chamber he was likewise quiet, but did a small amount of reading and writing to pass away the time.

The series of tables which embody the statistics of these experiments include a considerable number, of which four are cited herewith as specimens. Table 52 gives a summary of measurements of the volume of the ventilating air current and of the determinations of carbon dioxide in this current.

In table 53 is a corresponding summary of the determinations of water in the air current. Table 54 summarizes the heat measurements. The data briefly condensed in these tables were obtained during the four days of the actual metabolism experiment when the man was in the chamber. The full details, however, are quite extensive and are reserved, with the corresponding explanations, for later publication. Tables also too bulky for insertion here give the results of analyses and determinations of heats of combustion of the urine.

The data of these tables, and of those for the corresponding digestion experiments in the article on Experiments on Digestion of Food by Man (pages 154–167 of the present Report) are used for calculating the quantities of nutrients in the food

eaten, and the quantities digested and oxidized each day and during the whole four days of the experiment. The tables giving the results of these computations are similar to those in the Report of the Station for 1896 and in Bulletin No. 44 of the Office of Experiment Stations of the U. S. Department of Agriculture. The results are very briefly recapitulated in tables 55–58 beyond.

The detailed explanation of the method of calculation used in preparing these tables is given on pages 35–40 in Bulletin 44 of the Office of Experiment Stations previously referred to. Table 55 shows the income and outgo of nitrogen and carbon and the calculated gain or loss of these and of protein and fat.

TABLE 52.

Record of carbon dioxide in metabolism experiment No. 6.

Date.	Period.	Ventilation. Number of Liters of Air.	Carbon Dioxide per Liter. In Incoming Air.	Carbon Dioxide per Liter. In Outgoing Air.	Carbon Dioxide per Liter. Excess in Outgoing Air.	Total Excess in Outgoing Air.	Correction for Carbon Dioxide in Apparatus.	Corrected Wght. Carb. Diox. exhaled by Subject.	Total Weight C. exhaled in Carbon Dioxide.
		Liters.	Mg.	Mg.	Mg.	Grams.	Grams.	Grams.	Grams.
May 18–19,	7 A.M.–1 P.M.	25329	.905	17.190	16.285	412.5	+69.9	482.4	131.57
	1 P.M.–7 P.M.	21497	.994	23.520	22.526	484.2	+11.4	495.6	135.17
	7 P.M.–1 A.M.	22274	.771	13.769	12.998	289.5	—52.2	237.3	64.72
	1 A.M.–7 A.M.	22173	.730	7.435	6.705	148.7	—29.6	119.1	32.50
	Total, -	91273	—	—	—	1334.9	— 0.5	1334.4	363.96
May 19–20,	7 A.M.–1 P.M.	23364	.710	15.263	14.553	340.0	+76.4	416.4	113.55
	1 P.M.–7 P.M.	23356	.647	20.613	19.966	466.3	— 3.8	462.5	126.17
	7 P.M.–1 A.M.	23999	.587	13.651	13.064	313.5	—60.6	252.9	68.97
	1 A.M.–7 A.M.	23541	.606	6.381	5.775	136.0	—13.4	122.6	33.40
	Total, -	94260	—	—	—	1255.8	— 1.4	1254.4	342.09
May 20–21,	7 A.M.–1 P.M.	23147	.516	16.143	15.627	361.7	+90.5	452.2	123.35
	1 P.M.–7 P.M.	23044	.612	21.070	20.458	471.4	—33.8	437.6	119.35
	7 P.M.–1 A.M.	22423	.912	13.474	12.562	281.6	—41.1	240.5	65.60
	1 A.M.–7 A.M.	23344	.678	6.925	6.247	145.8	—10.4	135.4	36.94
	Total, -	91958	—	—	—	1260.5	+ 5.2	1265.7	345.24
May 21–22,	7 A.M.–1 P.M.	23268	.523	15.612	15.089	351.1	+74.6	426.7	116.08
	1 P.M.–7 P.M.	23031	.574	19.583	19.009	437.8	—32.5	405.3	110.55
	7 P.M.–1 A.M.	23833	.568	12.270	11.702	278.9	—50.0	228.9	62.41
	1 A.M.–7 A.M.	25757	.999	6.719	5.720	147.3	+ 0.8	148.1	40.40
	Total, -	95889	—	—	—	1215.1	— 7.1	1208.0	329.44
	Total, 4 days,	373380	—	—	—	—	—	5062.5	1380.73

TABLE 53.

Record of water in metabolism experiment No. 6.

Date.	Period.	Ventilation. Number of Liters of Air.	Water per Liter. In Incoming Air.	Water per Liter. In Outgoing Air.	Water per Liter. Excess in Outgoing Air.	Total Excess in Outgoing Air.	Condensed in Freezers.	Condensed in Chamber.	Correction for Water Vapor in Chamber.	Total Water Exhaled.
1897		Liters.	Mg.	Mg.	Mg.	Grams	Grams.	Grams.	Grams	Grams.
May 18–19,	7 A.M.–1 P.M.	25329	1.164	1.369	.205	5.2	279.1	483.2	+3.7	—
	1 P.M.–7 P.M.	21497	.955	1.546	.591	12.2	272.4	719.9	+6.6	—
	7 P.M.–1 A.M.	22274	1.055	1.273	.218	4.8	282.1	—	— .7	—
	1 A.M.–7 A.M.	22173	.752	1.090	.338	7.5	247.3	199.8	—9.7	—
	Total, -	91273	—	—	—	29.7	1080.9	1402.9	— .1	2513.4
May 19–20,	7 A.M.–1 P.M.	23364	.806	1.129	.323	7.5	258.3	445.5	+5.3	—
	1 P.M.–7 P.M.	23356	.938	1.269	.331	7.7	284.2	556.0	+3.0	—
	7 P.M.–1 A.M.	23999	.914	1.335	.421	10.1	298.9	—	— .3	—
	1 A.M.–7 A.M.	23541	.777	1.089	.312	7.2	267.9	81.0	+6.9	—
	Total, -	94260	—	—	—	32.5	1109.3	1082.5	+1.1	2225.4
May 20–21,	7 A.M.–1 P.M.	23147	.824	1.352	.528	12.1	264.3	504.6	—6.0	—
	1 P.M.–7 P.M.	23044	.900	1.371	.471	10.8	281.6	575.5	+9.8	—
	7 P.M.–1 A.M.	22423	.710	1.164	.454	10.2	280.9	—	— .7	—
	1 A.M.–7 A.M.	23344	.848	1.171	.323	7.6	273.1	85.3	—3.3	—
	Total, -	91958	—	—	—	40.7	1099.9	1165.4	— .2	2305.8
May 21–22,	7 A.M.–1 P.M.	23268	.798	1.134	.336	7.8	258.7	251.9	+5.8	—
	1 P.M.–7 P.M.	23031	1.124	1.361	.237	5.5	280.4	560.6	—6.7	—
	7 P.M.–1 A.M.	23833	.793	1.123	.330	7.9	295.0	—	—3.6	—
	1 A.M.–7 A.M.	25757	.870	1.042	.172	4.4	291.7	118.0	—3.1	—
	Total, -	95889	—	—	—	25.6	1125.8	930.5	—7.6	2074.3
	Total, 4 days,	373380	—	—	—	128.5	4415.9	4581.3	—	9118.9

The calculations in tables 55 and 56 beyond are partially explained by the letters and algebraic formulas at the tops of the columns. Thus column *d* indicates the gain or loss of nitrogen. That of the first day, for instance, is computed by adding the amounts in feces and urine as shown in columns *b* and *c* and subtracting their sum from the amount in the food as shown in column *a*. Table 56 shows the income and outgo of energy and compares the protein and energy in the food eaten with that estimated to be actually oxidized. The values given in columns *n*, *o* and *p* are actual heats of combustion as determined by the bomb calorimeter described in the preceding article of this Report. The values in columns *q* and *r* are

TABLE 54.—*Metabolism experiment No. 6. Summary of calorimetric measurements.*

Date.	Period.	Heat measured.	Correction for heat capacity of chamber.		Correction for heat capacity of absorbers.		Correction due to temperature of food and dishes.	Corrected heat.	Equivalent heat of water vaporized in chamber.		Total heat.	Heat equivalent of muscular work done.		
1897.		Calories	Degrees	Calories	Degrees	Calories	Calories	Calories	Grams	Calories	Calories	Minutes	Watts	Calories
May 18–19,	7 A. M.–1 P. M.,	1153	+.50	+30	—4.0	— 6	—12	1165	284.3	174	1339	238	42	143
	1 P. M.–7 P. M.,	1266	—.10	— 6	—2.0	— 3	—17	1240	284.5	175	1415	216	41	127
	7 P. M.–1 A. M.,	616	.25	—15	+6.3	+10	—12	599	286.9	175	774	—	—	—
	1 A. M.–7 A. M.,	298	.00	00	—1.3	— 2	0	296	254.8	156	452	—	—	—
	Total, - -	3333	—	+ 9	—	— 1	—41	3300	—	680	3980	—	—	270
May 19–20,	7 A. M.–1 P. M.,	1020	+.15	+ 9	—3.0	— 5	— 7	1017	265.8	162	1179	210	39	115
	1 P. M.–7 P. M.,	1150	+.05	+ 3	+1.7	+ 3	—12	1144	291.9	179	1323	124	39	70
	7 P. M.–1 A. M.,	586	—.05	— 3	+1.6	+ 2	—12	573	309.0	189	762	—	—	—
	1 A. M.–7 A. M.,	259	—.17	—10	0.0	0	0	249	275.1	168	417	—	—	—
	Total, - -	3015	—	— 1	—	0	—31	2893	—	698	3681	—	—	185
May 20–21,	7 A. M.–1 P. M.,	1116	—.13	— 8	—3.3	— 5	—16	1087	276.4	169	1256	236	40	135
	1 P. M.–7 P. M.,	1117	+.06	+ 3	0.0	0	—19	1101	292.5	179	1280	244	38	133
	7 P. M.–1 A. M.,	587	+.06	+ 4	+1.6	+ 2	—12	581	291.1	178	759	—	—	—
	1 A. M.–7 A. M.,	260	—.12	— 7	+0.6	+ 1	0	254	280.6	172	426	—	—	—
	Total, - -	3080	—	— 8	—	— 2	—47	3023	—	698	3721	—	—	268
May 21–22,	7 A. M.–1 P. M.,	1015	+.13	+ 8	—2.2	— 3	—10	1010	266.5	163	1173	224	39	125
	1 P. M.–7 P. M.,	1056	+.10	+ 6	+1.0	+ 2	—13	1051	285.9	175	1226	240	38	130
	7 P. M.–1 A. M.,	520	—.07	— 4	+3.6	+ 5	— 6	515	302.9	185	700	—	—	—
	1 A. M.–7 A. M.,	297	—.05	— 3	—1.1	— 2	0	292	296.1	181	473	—	—	—
	Total, - -	2888	—	+ 7	—	+ 2	—29	2868	—	704	3572	—	—	255
	Total, 4 days,	12316	—	+ 7	—	— 1	—148	12174	—	2780	14954	—	—	978

TABLE 55.—*Gain or loss of nitrogen, carbon, protein and fat in metabolism experiment No. 6.*

Day.	Nitrogen. In food.	Nitrogen. In feces	Nitrogen. In urine.	Nitrogen. Gain + Loss −	Protein Gain + Loss −	Carbon. In food.	Carbon. In feces.	Carbon. In urine.	Carbon. In resp'y products.	Carbon. Gain + Loss −	Carbon in protein gained + or lost −	Carbon in fat gained + or lost −	Fat Gain + Loss −
	a	b	c	d	e	f	g	h	i	j	k	l	m
				=a−(b+c)	=d×6.25					=f−(g+h+i)	=e×.53	=j−k	=l÷.765
	Gms.	Gms.	Gms.	Gms.	Gms.	Gms.	Gms.	Gms.	Gms.	Gms.	Gms.	Gms.	Gms.
First day,	19.1	1.5	17.5	+0.1	+ 0.6	333.9	12.3	13.1	364.0	−55.5	+0.3	−55.8	−72.9
Second day,	19.1	1.5	16.6	+1.0	+ 6.2	334.0	12.4	12.6	342.1	−33.1	+3.3	−36.4	−47.6
Third day,	19.1	1.5	15.4	+2.2	+13.8	333.9	12.3	11.7	345.2	−35.3	+7.3	−42.6	−55.7
Fourth day,	19.1	1.5	16.5	+1.1	+ 6.9	334.0	12.4	12.5	329.4	−20.3	+3.7	−24.0	−31.4
Total,	76.4	6.0	66.0	+4.4	+27.5	1335.8	49.4	49.9	1380.7	−144.2	+14.6	−158.8	−207.6
Average per day,	**19.1**	**1.5**	**16.5**	**+1.1**	**+ 6.9**	**334.0**	**12.4**	**12.5**	**345.2**	**−36.1**	**+3.6**	**−39.7**	**−51.9**

TABLE 56.—*Income and outgo of energy in metabolism experiment No. 6.*

Day.	Energy. (Heats of Combustion.) Actually Determined. Of food.	Actually Determined. Of feces.	Actually Determined. Of urine.	Estimated. Of protein gained + or lost −	Estimated. Of fat gained + or lost −	Estimated. Of mate'l actually oxidized in body.	Heat actually measured	Protein. In food.	Protein. Actually oxidized.	Energy. Of food.	Energy. Of material actually oxidized.
	n	o	p	q	r	s	t	u	v	w	x
				=e×5.5	=m×9.4	=n−(o+p+q+r)		=a×6.25	=c×6.25	=n	=s
	Cal.	Cal.	Cal.	Cal.	Cal.	Cal.	Cal.	Gms.	Gms.	Cal.	Cal.
First day,	3678	139	127	+ 3	− 685	4094	3980	119.4	109.4	3678	4094
Second day,	3678	139	132	+ 34	− 447	3820	3681	119.4	103.7	3678	3820
Third day,	3678	139	119	+ 76	− 524	3868	3721	119.4	96.3	3678	3868
Fourth day,	3678	139	123	+ 38	− 295	3673	3572	119.4	103.1	3678	3673
Total,	14712	556	501	+151	−1951	15455	14954	477.6	412.5	14712	15455
Average per day,	**3678**	**139**	**125**	**+ 38**	**− 488**	**3864**	**3739**	**119.4**	**103.1**	**3678**	**3864**

obtained by the use of factors representing the average heat of combustion of one gram of protein and fat respectively. The values in the column *t* are obtained from table 54.

Tables 57 and 58 recapitulate the final results of metabolism experiments Nos. 6 and 9. Those for No. 6 are taken from the tables just described. Those for No. 9 are from similar tables not quoted here.

TABLE 57.

Average daily income and outgo of nitrogen and carbon in metabolism experiments Nos. 6 and 9, with the estimated gain or loss of protein and of fat.

No. of Experiment.	Date, Subject and Occupation.	Nitrogen.				Carbon.					Calculated Gain or Loss.	
		In Food.	In Feces.	In Urine.	Gain + or Loss −.	In Food.	In Feces.	In Urine.	In Respiratory Products.	Gain + or Loss −.	Of Protein.	Of Fat.
		Gms.	Gm	Gms.	Gms.	Gms.	Gms.	Gms.	Gms.	Gms.	Gms.	Gms.
6	May, '97, E. O., work,	19.1	1.5	16.5	+1.1	334.0	12.4	12.5	345.2	−36.1	+6.9	−51.9
9	Jan., '98, E. O., rest,	19.1	1.3	18.4	− .6	254.7	12.9	12.6	223.6	+5.6	−3.6	+9.8

TABLE 58.

Comparison of daily income and outgo of protein and energy in metabolism experiments Nos. 6 and 9.

No. of Experiment.	Date, Subject and Occupation.	Protein.		Energy.			
		Of Food.	Actually Oxidized.	Of Food.	Of material actually oxidized.	Measured.	Diff. in % of heat of material actually oxidized.
		Gms.	Gms.	Cal.	Cal.	Cal.	%
6	May, 1897, E. O., work, -	119.4	103.1	3678	3864	3739	3.2
9	January, 1898, E. O., rest, -	119.4	115.0	2717	2354	2329	1.1

It will be observed that in both of these experiments the outgo of energy, *i. e.*, the heat given off from the body and the heat equivalent of the external muscular work done, as measured by the respiration calorimeter, is less than the income or estimated heat of combustion of food and body material actually oxidized.

This difference in experiment No. 6 amounts to 3.2 per cent. and in experiment No. 9 to 1.1 per cent. of the energy of the material oxidized. This discrepancy may be due to errors of experiment, of which several are possible. One may be found in the sampling of the food materials. Our experience has shown that the error from this source may be much larger than is commonly supposed. Special measures for avoiding it were adopted in later experiments, in which the discrepancies were considerably less, as in No. 9. Another important source of error may perhaps be sought in the composition of the materials gained or lost in the body, and in their assumed heats of oxidation. A very similar source of error, and one perhaps the most difficult to eliminate, is the variation in the amount of material actually absorbed from the alimentary tract. It is not unreasonable to assume, however, that after a four days' preliminary experiment in which a constant diet is used the rate of assimilation is fairly constant, and that the material actually absorbed on the last day will not vary materially from that absorbed on the first day of the respiration experiment proper.

Of the other sources of error there was one of special consequence in this experiment. The muscular work of the subject was at times rather severe, and the heat was developed within the apparatus at a rapid rate, and the changes in temperature inside the chamber were considerable. We are inclined to think that the heat measurements under these circumstances were less accurate than usual, and that minor modifications of the apparatus may be needed to provide for greater accuracy in experiments of this class.

The experience in handling the apparatus and in sampling and analyzing the food has been used in a number of experiments since No. 6, of which No. 9 is one. In these later experiments, the details of which are soon to be published, the differences between income and outgo of energy range from 2.2 to 0.4 per cent. and average about 1.2 per cent. That is to say, in these more accurate experiments about 99 per cent. of the potential energy of the material metabolized and oxidized in the body is accounted for in the kinetic energy given off in the forms of heat and external muscular work.

In how far this fairly close agreement is due to a counterbalancing of errors it is impossible now to say. But in view

of the physiological difficulties in the way of absolutely accurate results, and the evident possibilities of minor errors in the purely chemical and physical determinations, this agreement seems to us very satisfactory as marking a stage in the development of the apparatus and methods, and sufficient to warrant some extended series of experiments upon various questions connected with the laws of nutrition. Such experiments are now being carried out. Efforts are being made at the same time to eliminate part at least of the experimental errors. At present these are chiefly in the direction of improvement of methods of sampling and analyzing the food materials and excretory products, the finding of minor sources of error in the determinations of carbon, hydrogen and heat given off in the respiration chamber, and the direct determination of the oxygen of income and outgo. Minor alterations are also being made in the apparatus and the methods of its manipulation by which it is hoped that somewhat greater accuracy may be secured.

THE CONSERVATION OF ENERGY IN THE LIVING ORGANISM.

It is commonly assumed that the law of the conservation of energy applies in the living organism; that, in other words, the metabolism of energy in the plant and in the animal takes place in accordance with the same physical laws that obtain elsewhere. While there seems no reason to doubt this principle it has lacked the final proof of exact experiment. Gradual approaches toward such demonstration have been made from time to time. Meanwhile, awaiting this absolute demonstration, physicists, chemists and physiologists generally, if not universally, assume the correctness of the principle.* The experimental inquiry of later years has brought results which strongly confirm it. This is notably the case with the experiments of Rubner.† In these, which were made as a study of the source of animal heat, the subjects were two dogs weighing about 5 and 12 kilograms respectively. In some of the experiments the animals fasted; in others they had lean meat

* For an early discussion of the subject see J. R. Mayer, *Die organische Bewegung in ihrem Zusammenhange mit dem Stoffwechsel;* Heilbronn, 1846.
See also Rubner, *Die Quelle der thierischen Wärme;* Zeitschrift für Biologie, 30, 1894, pp. 73-86, and W. O. Atwater, Methods and Results of Investigations on the Chemistry and Economy of Food, Office of Experiment Stations of the U. S. Department of Agriculture, pp. 113-135.
† Loc. cit.

to furnish protein, or bacon to furnish fat, or both. They were placed inside the chamber of a respiration calorimeter especially devised by Rubner for determining the respiratory products and the heat given off from the body. The determinations actually made were: the weight of the animal at the beginning and the end of the experiment, of food and water given, and of urine and feces; the percentages of fat in the food and of nitrogen in the feces and in the urine; the weights of carbon dioxide and water in respiratory products; and the calories of heat given off from the body. The nitrogen was not determined in the food; the carbon was not determined in the food, feces, or urine and no nitrogen nor carbon balance was made. The amounts of food and body materials oxidized were calculated from the nitrogen and carbon excreted. The heat of combustion of these oxidized materials was calculated from the calculated amounts, and assumed heats of combustion. No determinations were made of heats of combustion of food or excretory products.

For the balance of energy the income was calculated from the estimated amounts of material oxidized in the body, and the outgo was found in the determination of the heat given off from the body. Nine experiments were made, the periods ranging from one to twelve days, the total number of days being forty-five. The differences of estimated income and outgo of energy in the individual experiments ranged from about —5.2 to +3.2 per cent. of the total energy but in most cases they were very small indeed, and the average for the whole forty-five days showed a difference of less than one-half of 1 per cent. It was assumed by the author that all of the energy given off from the bodies of the animals was in the form of heat. In his opinion these experiments furnish a proof that the nutrients of the food and the body materials consumed are the sole sources of heat in the animal body. There can hardly be a doubt that the opinion is justifiable and the experiments thus confirm the belief that the law of the conservation of energy applies in the living organism,*

* Late experiments by Studenski with dogs have brought results entirely in the line of those of Rubner. Unfortunately, however, the description is published in Russian and the only account accessible to us has been a brief abstract in English. For reference to these experiments as well as for an account of those of Rubner and a general discussion of the subject, see "A digest of Metabolism Experiments," by W. O. Atwater and C. F. Langworthy, Bulletin 45 of the Office of Experiment Stations of the U. S. Department of Agriculture, Washington, 1897, p. 416.

even though the data of the experiments have not all the completeness that is to be desired.

In the experiments here described the energy of outgo includes both the heat given off from the body and, in one case, that of a considerable amount of external muscular work. The income and outgo agree as closely perhaps as could be expected in view of the possible sources of error.

In experiment No. 9, the disagreement is about as large as in the average of the later and more accurate experiments. The income here exceeds the outgo by about 25 calories per day. This quantity is really quite small. It would correspond to the potential energy of about one-tenth of an ounce of body fat, or nearly the same weight of butter, or one-fourth of an ounce of sugar, or one-third of an ounce of bread.

It may be that a small part of the energy which is transformed in the body is given off in some form which the apparatus and methods here used are incapable of measuring. It is, for instance, conceivable that intellectual activity may be accompanied by the evolution of energy in some other form than heat. These, however, are matters of speculation.

We should, of course, be unwarranted in assuming that these experiments completely demonstrate the action of the law of the conservation of energy in the human organism. They do, however, seem to us to be reasonably near to such demonstration, for the cases in which they were made.

USE OF THE PRINCIPLE IN FURTHER RESEARCH.

It is certainly safe to assume that the principle is correct, and the apparatus and methods are accurate to the degree required for the experimental study of a large variety of the fundamental problems of biological chemistry and physics. Among these are the metabolism of energy and the production of heat by the body in the performance of its ordinary functions, as circulation, respiration and digestion; the relations of muscular and mental work to the metabolism of matter and energy; the demands of the body for nutriment under different conditions of work and rest; the duties performed by the different nutrients of food in supplying the needs of the body; and finally, the nutritive values of food materials and the amounts and proportions best adapted to the needs of the people

of different classes, with different occupations, and in different conditions of life. That such inquiries may be valuable for the study of food and nutrition in disease is equally apparent. Of course they are fundamentally necessary for more thorough understanding of the economy of feeding domestic animals.

SUMMARY.

The experiments with the respiration calorimeter here described had a two-fold purpose; to test the accuracy of the apparatus and methods, and to determine the balance of income and outgo of matter and energy in the body. They are preliminary to more extended research upon some of the fundamental problems of nutrition.

The apparatus consists essentially of a metal-walled chamber in which a man lives, eats, drinks, works, and sleeps. Provision is made for ventilating the chamber and for regulating the temperature and moisture of the air within it. The volume of air in the ventilating current is measured; the food, drink, excreta, and respiratory products are weighed and analyzed, and their potential energy is determined, as is the kinetic energy given off from the body in the forms of heat and external muscular work.

The accuracy of the apparatus and methods for the determinations of carbon dioxide, water, and heat was tested by heat generated in the chamber by passing an electric current through a resistance coil, and by burning ethyl alcohol within the chamber. In the electrical tests the measurements of heat generated and found were practically identical. In the alcohol tests the average amounts found by actual experiment were: for carbon, 99.6 per cent.; hydrogen, 100.6 per cent.; and heat 99.8 per cent. of the theoretical amounts. It thus appears that this apparatus when used for the analysis of alcohol and the determination of its heat of combustion gives results nearly, if not quite, as accurate as are obtained by the ordinary laboratory methods.

A series of experiments with men have been undertaken, two of the earlier of which are here reported. These are intended for the study of several problems. The question especially considered here is this: Is the energy given off from the body in the form of heat, or of heat and external muscular work, equal to the potential energy or heat of combustion of the material actually burned in the body? In other words, when the compounds of the food and

the body—proteids, fats, and carbohydrates—are burned, is their potential energy transformed into the equivalent kinetic energy and into forms which can be measured by the means here used? Or, to state the question more broadly, does the law of the conservation of energy obtain in the living organism?

The experiments with a man each continued during eight days, during the last four days and five nights of which the subject was in the respiration chamber. The diet during each experiment was uniform through the whole eight days. The purpose of the preliminary period of four days was to bring the body into at least approximate nitrogen and carbon equilibrium with the food and to make the determination of the amounts of nutrients absorbed as nearly accurate as practicable. The income and outgo of nitrogen were determined during this period, which thus amounted to a digestion and metabolism experiment. The metabolism of nitrogen, carbon, hydrogen, and energy was determined during the final period of four days.

In one of the two experiments the man had as little muscular exercise as he could well have with comfort. In the other he was engaged in quite active muscular exercise. The external muscular work was expended in driving a dynamo which produced an electric current. The latter was passed through a resistance coil and the energy was transformed into heat which was measured with that given off from the body.

The differences between the income and outgo of energy as measured in these two cases were 3.2 and 1.1 per cent., and averaged 2.2 per cent. The amount of energy as measured was in each case less than the theoretical amount of potential energy in the material consumed. The larger discrepancy was in the first experiment. Certain sources of error in this appear to have been eliminated, at least in part, in later experiments, of which the second was one. In these latter the agreement is very close, the energy found being about ninety-nine per cent. of the theoretical. On the whole the agreement between theoretical amounts of energy transformed and those found in the experiments is as close as could be expected under the circumstances.

It would be wrong to assume that these experiments demonstrate completely the conservation of energy in the animal organism. They do, however, approach very closely to such demonstration for the case of the man under experiment.

In conclusion mention should be made of the coöperation of several gentlemen in the work above described. Mr. O. S. Blakeslee has not only devised and made the meter-pump and other apparatus as above stated, but has also given many valuable suggestions and rendered useful aid in the working out of other details of the respiration calorimeter and accessory apparatus. The calculations of the results of the experiments and preparation of the tables has been done very largely by and under the direction of Mr. A. P. Bryant. Mr. H. M. Burr has made a large number of analyses besides assisting in the conducting of the experiments and in various other ways. The determinations of the heats of combustion are largely the work of Dr. O. F. Tower, who has contributed materially to the analytical and other details of the experiments. Mr. A. W. Smith has been connected with the calorimetric side of the work for several years and has had much to do with the conduct of the heat measurements. A large part of the electrical tests above referred to were made by him. In both the planning and the execution of this part of the investigation his services have been most useful.

A large amount of most valuable suggestion and help in the development of the apparatus and methods has come from Dr. F. G. Benedict, to whose skill and ingenuity several of the important features of the apparatus are due and who has had an important share in the general supervision of the experiments. His name has appeared as joint author of the previous, and will have the same relation to future, experiments.

TUBERCULOUS COWS AND THE USE OF THEIR MILK IN FEEDING CALVES.

BY C. S. PHELPS.

Early in the fall of 1896 arrangements were made with the Connecticut State Cattle Commission by which four condemned Devon cows were placed at the disposal of the Station. The herd from which the animals came was officially tested with tuberculin by the Cattle Commissioners in March, 1896, and several of its number were condemned and slaughtered. At that time the four animals which were later taken for experiment failed to respond (see page 244). These were officially tagged as free from the disease and were numbered 1337, 1341, 1343, and 1344.

In October, 1896, the herd was again tested with tuberculin by the same Commissioners and the four cows just referred to responded to the test (see page 244), and shortly after were placed at the disposal of the Station.

The appearance of the disease in animals which seven months before were pronounced sound may, perhaps, be accounted for in one of three ways. First: The disease may have been present at the time of the first test, and, through failure on the part of the tuberculin to react, its presence was not revealed. Second: At the time of the first test the germs may have but recently found lodgment in the animals. In this case the disease might have been so little developed as not to cause a response to the test. Third: The disease germs may have been acquired after the first test owing to insufficient care in disinfecting. The owner had been accustomed to feed grain in movable boxes which were shifted from manger to manger without regard to cows. Through an oversight these boxes were not destroyed nor disinfected, but their use was continued in the same indiscriminate manner as before. Boxes thus used would, with little doubt, afford a place for the lodgment of the germs and a means for their spread from one animal to another.

These particular animals were chosen for experiment, because there was good reason to believe that the disease was present

in its earlier stages. One object in view in the experiment was to study the effect of the milk of slightly diseased cows when fed to healthy calves.

TABLE 59.

*Tuberculin tests made with cows prior to their arrival at the Station.**

NUMBER OF COW.	BEFORE INJECTION.		AFTER INJECTION.				
	8 P. M.	10 P. M.	6 A. M.	8 A. M.	10 A. M.	12 M.	2 P. M.
Test made March 14-15, 1896.							
1337, - - - -	102.2	102.8	102.3	102.6	103.0	102.4	102.4
1341, - - - -	101.1	101.3	101.6	102.2	102.2	102.4	102.0
1343, - - - -	101.0	101.6	101.8	101.8	102.1	102.1	102.2
1344, - - - -	101.0	101.5	100.7	101.6	101.4	102.0	101.4
Test made October 26-27, 1896.							
1337, - - - -	101.3	101.4	100.6	101.6	103.0	104.4	104.8
1341, - - - -	101.6	101.4	100.8	101.7	102.4	104.4	105.6
1343, - - - -	102.0	101.7	99.6	101.6	102.8	104.4	105.0
1344, - - - -	101.8	101.1	102.0	102.0	105.0	105.8	105.6

* Through the courtesy of the former Secretary of the State Cattle Commission we are able to publish the temperatures obtained in the tuberculin tests made prior to the arrival of the cows at the Station. These tests were made by Dr. L. J. Storrs.

Care of the Cows, and Tuberculin Tests after they were taken in charge by the Station.—When the cows were brought to the Station they were placed in high, light, and airy stables affording about 1,500 cubic feet of air space per cow, although later three calves occupied the same stables with the cows. Adjoining the stables was a yard about one-half acre in area, where the animals could exercise. In mild weather they occupied the yard most of the day. No special treatment for the disease was attempted, but good care and feed were afforded at all times. Plans were made whereby the animals could be subjected to the tuberculin test from time to time. These tests were made wide apart (from two to four months), with the thought that perhaps the animals would not be as likely to become immune* to the effects of the tuberculin, and thus later fail to respond. The animals, however, failed to respond to later tests, although it is, perhaps, doubtful if this can be

* By immune or immunity, as here used, is meant a supposed power of resistance by the animal to the ordinary effects of tuberculin, caused by repeated injections, so that no rise of temperature results.

ascribed to immunity to the tuberculin, as some animals failed to respond for several months and later did respond, while others have not responded for more than a year, although tested several times.

The first test after the cows reached the Station was made by the College Veterinarian, Dr. George A. Waterman, January 26–27, 1897. This was three months after the animals were condemned by the Cattle Commissioners. All four of the cows responded clearly to the test. In addition to the necessary rise of temperature to indicate the presence of the disease, cow No. 1337 showed a roughness of the hair at 9:30 A. M., the 27th, and Nos. 1341, 1343, and 1344 each showed a decided chill between 9:30 A. M. and 3:00 P. M. The next two tuberculin tests were made by the same veterinarian. Three months later, April 26–27, all four of the cows were injected. At that time cows No. 1341 and 1344 responded to the test, while the other two cows showed no apparent results. None of the cows manifested any signs of chill. The next test was made about four months later, July 30–31. At that time none of the cows gave any appreciable rise of temperature nor did they manifest any physical symptoms, such as chilling or roughness of the hair. Late in September it was thought desirable to repeat the test, and as the College was temporarily without a Veterinarian, the services of Dr. L. J. Storrs were engaged. No response either in rise of temperature or physical symptoms could be observed.

The tuberculin tests which were made in December, 1897, and April, 1898, were conducted by Dr. N. S. Mayo, the present College Veterinarian. In these tests the temperatures before injection were taken every three hours throughout the day. As these varied but slightly only the averages for the day are given in the table. In the test made December 17–18, cow No. 1344 gave a marked rise of temperature while the other three showed no response. The last test previous to the publishing of this Report was made April 11–12, 1898. At that time cow No. 1343 responded while the other three cows did not. Cow No. 1344 showed a slight rise of temperature at 4, 6, and 8 P. M., the day after injection, but she was observed to be in heat at this time, a condition which would doubtless account for a slight abnormal temperature.

Table 60.

Tuberculin tests of tuberculous cows, and of calves which were fed their milk.

Date of Test and Number of Animal.	Before Injection.		After Injection.							
	5 P.M.	9 P.M.	6 A.M.	8 A.M.	10 A.M.	12 M.	2 P.M.	4 P.M.	6 P.M.	8 P.M.
Jan. 26–27, 1897.										
1337, -	101.0	101.2	101.5	102.1	**104.0**	**105.2**	**106.1**	—	**104.8**	—
1341, -	102.2	101.5	102.1	102.5	103.6	102.6	103.2	**104.9**	**106.1**	—
1343, -	100.9	100.3	101.4	102.0	102.9	**105.1**	**106.2**	—	**105.0**	—
1344, -	100.6	100.1	101.2	101.6	103.0	**105.0**	**105.9**	—	**105.6**	—
A (calf), -	102.0	102.0	101.5	101.1	101.4	101.6	101.6	—	102.2	—
March 3–4.	4 P.M.									
B (calf), -	102.7	103.4	102.1	102.6	102.2	101.5	101.7	—	—	—
Mar. 29–30	5 P.M.									
A (calf), -	102.4	102.6	102.4	102.0	101.7	101.9	102.4	—	—	—
Apr. 26–27.										
1337, -	103.7	102.0	102.4	102.2	102.0	102.2	102.0	—	—	—
1341, -	102.8	101.5	102.6	103.7	**105.2**	**106.0**	**105.8**	—	—	—
1343, -	102.0	101.6	102.0	102.0	102.2	102.0	101.8	—	—	—
1344, -	101.6	101.0	102.5	103.4	**103.8**	**103.8**	102.8	—	—	—
July 30–31.		11 P.M.								
1337, -	101.8	101.3	102.2	102.0	102.2	102.1	102.2	101.3	102.4	102.1
1341, -	101.6	101.0	102.5	102.8	101.9	101.8	101.5	101.2	101.3	101.0
1343, -	101.8	101.0	102.8	102.7	102.1	102.2	102.0	101.8	101.4	101.4
1344, -	101.1	100.6	102.1	102.4	101.7	102.0	102.0	102.0	102.0	101.0
A (calf), -	102.5	101.8	101.8	101.8	101.4	102.0	101.8	—	—	—
B (calf), -	101.8	101.9	101.2	101.4	101.6	101.6	101.9	—	—	—
C (calf), -	103.0	102.0	101.8	101.5	101.7	101.8	102.4	—	—	—
Sept. 27–28.	8 P.M.	10 P.M.								
1337, -	—	101.8	102.0	102.1	101.9	101.6	101.6	—	—	—
1341, -	—	101.5	101.3	101.2	101.5	102.0	101.8	—	—	—
1343, -	—	101.7	101.5	101.6	101.5	101.3	101.5	—	—	—
1344, -	—	101.0	101.1	101.4	101.2	101.2	101.1	—	—	—
A (calf), -	102.6	101.6	101.6	101.4	101.7	101.8	102.0	—	—	—
B (calf), -	102.3	101.7	101.7	101.3	101.0	101.2	101.5	—	—	—
C (calf), -	102.4	101.6	101.8	101.4	101.7	101.8	101.8	—	—	—
Dec. 17–18.		Inject. 12 P.M.								
1337, -	—	101.6*	101.3	101.7	102.9	102.9	102.6	102.5	103.0	103.5
1341, -	—	101.3*	101.2	102.0	102.3	103.0	102.2	102.6	102.1	101.5
1343, -	—	101.5*	101.1	102.0	101.9	102.4	102.0	101.8	101.0	101.8
1344, -	—	101.0*	101.5	102.2	**104.4**	**106.4**	**107.0**	**105.7**	**104.4**	102.8
A, - -	—	101.1*	100.8	101.8	101.6	101.6	100.9	102.2	101.8	101.0
B, - -	—	101.3*	101.0	101.2	101.0	101.2	101.9	101.7	102.2	100.8
C, - -	—	101.4*	101.0	101.5	101.2	101.4	101.7	101.7	102.2	101.4
D (calf), -	—	102.1*	102.0	101.7	101.2	102.0	101.8	102.0	102.0	102.0

TABLE 60.—(*Continued.*)

DATE OF TEST AND NUMBER OF ANIMAL.	BEFORE INJECTION.		AFTER INJECTION.							
	5 P. M.	9 P. M.	6 A. M.	8 A. M.	10 A. M.	12 M.	2 P. M.	4 P. M.	6 P. M.	8 P. M.
Apr. 11–12, 1898.		Inject. 12 P. M.								
1337,	—	101.3*	101.8	102.6	102.3	102.2	101.8	101.8	101.9	102.0
1341,	—	101.3*	102.0	102.6	102.4	102.6	101.9	102.0	101.8	101.6
1343,	—	101.5*	102.3	**104.0**	**104.2**	**104.5**	**104.0**	102.5	101.9	102.0
1344,	—	100.8*	101.7	102.5	102.7	102.8	102.7	103.0†	103.2†	103.0†
A,	—	101.4*	101.6	101.8	101.6	102.0	101.8	101.3	102.0	102.0
B,	—	100.9*	100.5	101.0	100.6	100.6	100.8	100.5	101.4	101.4
D (calf),	—	101.8*	102.3	101.8	101.7	101.7	102.0	102.7	102.6	102.6

* Average of temperatures taken every three hours, 6 A. M.–12 P. M.
† Noticed to be in heat at 8 P. M.

On summarizing the tuberculin tests since the cows arrived at the Station we find that cow No. 1337 responded in January, 1897, did not respond in April, July, September, or December, 1897, nor in April, 1898. Cow No. 1341 responded in January, and in April, 1897, did not respond in July, September, or December, 1897, nor in April, 1898. Cow No. 1343 responded in January, 1897, did not respond in April, July, September, or December, 1897, but did not respond in April, 1898. Cow No. 1344 responded in January and April, 1897, did not respond in July or September, responded in December, 1897, but failed to respond again in April, 1898.

PHYSICAL CONDITION OF THE COWS FROM OCTOBER, 1896, TO APRIL, 1898.

Cows No. 1343 and 1344 dropped calves in September or October, 1896, and have continued to produce milk up to the present writing (April, 1898). While the flow has not been large it is perhaps up to the average for cows of this breed. These two cows have remained in good condition of flesh for the past year and a half. No. 1343 is a lighter milker than No. 1344 and has become quite fat and sleek. Since March 1st, 1898, she has had a slight cough, but otherwise has apparently remained in good physical condition. Cow No. 1344 was rather thin in flesh during the summer and fall of 1897, but within the past three months has gained in flesh and at present appears in "good order" for a milch cow. Cows No. 1341 and 1337 were dry for about three months during the winter

of 1896–97. Cow No. 1341 dropped a dead calf March 2d, 1897. The time she was due to calve was not known, but the fetus appeared to be premature by about one month. Careful physical examination of the dead calf made by the College Veterinarian failed to show the presence of tuberculosis and cultures made from several sections of the body failed to reveal germs of tuberculosis. This cow was thin in flesh for about three months after calving, but gained slightly during the summer. For six months after calving she continued to give quite a large flow of milk and this may have tended to keep her thin in flesh. During the past winter (1897–98) she has gained in flesh, and, at present (April, 1898), appears in fair physical condition. Cow No. 1337 was a heifer which had produced one calf prior to coming to the Station. She remained in fair flesh during the winter of 1896–97, and was dry about three months. She dropped a strong heifer calf on April 5. From birth till September 20th the calf sucked its dam, and the latter seemed a little thin in flesh, although not noticeably so considering her condition of milk. This cow has gained in size and flesh during the winter of 1897–98, and, at present (April, 1898), is in "good order."

FEEDING CALVES WITH THE MILK OF TUBERCULOUS COWS.

Soon after the cows were brought to the Station plans were made for feeding their milk to calves from healthy cows. Calf A was dropped December 25, 1896, by a vigorous grade cow. The dam of the calf on March 3 and 4, 1897, gave no response to the tuberculin test. The milk of cow No. 1344 was fed to this calf from January 7 to March 28. The calf was tested with tuberculin January 26 and 27, and again March 29 and 30, but gave no response to the test. At that date, the supply of milk from this cow being less than the calf needed, it was fed the milk of cow No. 1341, being limited to about fifteen or sixteen pounds per day for the first month. After this calf A was allowed all of the milk given by cow No. 1341, twenty to twenty-four pounds daily for the next two months, and has continued to consume the full milk supply of this cow up to date (April, 1898). Besides the two tuberculin tests made early in the feeding period, calf A was tested July 30 and 31, September 27 and 28, and December 17 and 18,

1897, and on April 11 and 12, 1898. At no time has this calf shown any effects from the tests or any physical symptoms that would indicate the presence of the disease. It is now a large vigorous animal weighing about 500 pounds.

About March 1st, 1897, calf B was chosen to consume the milk of cow No. 1343. This calf was dropped by a vigorous Jersey cow on February 20, 1897, and was ten days old when the feeding period began. The dam of the calf was tested with tuberculin about a year previous to the birth of this calf and was pronounced healthy. Calf B, when two weeks old (March 3 and 4), was tested with tuberculin and gave no response. From March 1st, 1897, up to the present time (April, 1898), calf B has been fed the entire milk supply of cow No. 1343. This calf has not been a vigorous eater, and at times has refused single feeds of milk. The calf has seemed healthy and has eaten hay readily. It is rather small for its age, but this may be due to the fact that the calf has always refused grain feeds. Besides the test with tuberculin at the beginning of the feeding period, calf B was also tested July 30–31, September 27–28, and December 17–18, 1897, and April 11–12, 1898.

The heifer calf (C) dropped by cow No. 1337, April 5th, 1897, was allowed to suckle its dam till about six months' old, and, except for a short time after birth, consumed all of the milk given by the cow. About October 1st the calf was weaned, but was fed the milk of the dam till January, 1898. At this time the calf was gradually changed on to a mixed skim milk diet and was placed in the College herd, the intention being to rear the calf for breeding purposes. Calf C was tested with tuberculin July 30–31, September 27–28, and December 17–18, 1897. The calf has made a rapid growth from the start, and at the present writing (April, 1898), gives promise of developing into a large and vigorous cow. It is our purpose to subject this animal to the tuberculin test from time to time to get check of a possible later development of the disease.

Calf D was dropped by a vigorous grade cow November 29, 1897. The cow was tested with tuberculin March 3–4, 1897, and gave no response to the test. The calf was first subjected to the tuberculin test December 17–18 and gave no response. Again, on April 11–12, 1898, this calf was tested, but gave no response. The calf has had all the milk produced by cow No.

1344 (10–12 pounds daily) during the past winter, and, in addition, a small amount of dry grain feed and hay. It has made a rapid growth and appears vigorous and healthy.

The following statement by the College Veterinarian is appended to this article in order to show the present condition of the cows as far as a physical examination will indicate. It was made May 8, 1898, while this Report is being printed:

It is a fact well recognized, that bovine tuberculosis, unless well advanced, is one of the most difficult diseases to diagnose upon a physical examination.

Of the seven animals examined four are the Devon cows that have been tested and found to respond at one time or another, three (A, B, and D) are young bulls that have been fed with the milk of the cows. The calves have not reacted to the tuberculin test and a careful physical examination fails to reveal any indications that they have tuberculosis.

Of the four cows that have responded to the test, No. 1337 presents no symptoms of tuberculosis. She is in good flesh, and looks well. Her temperature was 102° F., respirations full and at the rate of twelve per minute.

Cow No. 1341 is thinner in flesh than any of the others and seems to be affected with a slight but chronic looseness of the bowels. Her temperature was 102.2° F., and respirations twelve per minute.

Cow No. 1343 is rather fat. She is troubled with a chronic cough, and auscultation indicates that the anterior (cephalic) lobes of the lungs, especially the right, are tuberculous. Her temperature was 102.6° F., and respirations are twenty-two per minute. Cows No. 1337, 1341, and 1343 are pregnant.

Cow No. 1344 is in good flesh. Temperature 101.8° F., and respirations fifteen per minute. Nothing abnormal could be detected upon a physical examination. No enlarged glands could be detected in any of the animals examined. Of the four cows that have at some time responded to the test, Nos. 1337 and 1344 show no symptoms of the disease having developed. In No. 1341 the chronic looseness of the bowels may be considered as a suspicious symptom of a tubercular affection of the digestive tract. In No. 1343 the physical symptoms indicate tuberculosis of the lungs.

It must be remembered that all of these animals have had good care and attention and have not been exposed to conditions or circumstances that would cause the disease to develop.

N. S. MAYO,
College Veterinarian.

DEDUCTIONS.

Our definite knowledge of tuberculosis is of recent origin and is limited at the best. We know comparatively little regarding the conditions which favor its spread and development, either among animals or man. Most of all are we lacking in definite knowledge of the dangers of the disease to mankind from the bovine race. New experiments and new discoveries may so modify our views as to make present conclusions of

little value. These facts must be borne in mind in attempting to make deductions from experiments. Owing to the short time these experiments have been in progress it would be unwise to attempt to draw any definite conclusions from the work, but the following deductions based on these and other observations and experiments seem warranted:

1. Bovine tuberculosis is usually a disease of slow development, depending for its progress on conditions which favor the spread of the specific germs, and the extent to which the animal organism may be subject to these germs, owing to bad surroundings, poor ventilation, etc. The general vigor of the animal, or its power to resist the action of the germs, will also affect the progress of the disease.

2. The stage at which the disease may attack the udder of the cow, or become so generalized as to develop the germs in the lacteal ducts, is a matter of more or less uncertainty. In the earlier stages of the disease, or when no physical symptoms appear, such as hard lumps, or stringy, or "gargety" looking milk, udder affection is comparatively rare. Increasing evidence tends to imply that there is little danger of spreading the disease by the use of milk of diseased cows so long as the udders remain unaffected.

3. Calves fed on the milk of tuberculous cows with no udder affection are not liable to acquire the disease from this source. In the tests made at this Station calves have been fed for periods of five to sixteen months upon the milk of cows which it is reasonable to suppose are tuberculous, but without the disease having appeared in the udder, and in no instance do these calves show symptoms of the disease either by the tuberculin test or physical examinations.

METEOROLOGICAL OBSERVATIONS.

BY C. S. PHELPS.

The meteorological observations made at the Station during 1897 have been similar to those of past years. The Station equipment consists of the ordinary instruments for observing temperatures, pressure of the air, humidity, rainfall and snowfall, uniform with those used by voluntary observers for the United States Weather Service. In addition to the records made at Storrs, the rainfall for the summer season (May 1—October 31) has been recorded by quite a number of farmers in coöperation with the Station.

The total precipitation for the year (53.0 inches), as measured at Storrs, was considerably above the average yearly precipitation for this State, and was the highest since this Station began its observations in 1888. The average annual precipitation for Connecticut, as near as can be estimated from observations covering periods of from five to thirty years, is 48.5 inches. The average from fifteen observers in this State having records covering the five years 1891–95 is 44.7 inches. The average for the past nine years at Storrs is 45.2 inches. The average precipitation for 1897 is therefore 4.5 inches above the general average for the State and 8 inches above the average for nine years at Storrs. The highest previous record at this Station was in 1891 (51.6 inches). The rainfall was especially heavy during the months of July, August, November and December, and was well distributed throughout the balance of the year. During the early part of the season there was sufficient to start a vigorous growth of all crops, but much damage was caused to grass and some other crops by the excessive rains of July and August.

The temperature for January, February and March was about normal. April was rather cold and spring work did not begin as early as usual. The last killing frost occurred April 22. The temperature for the summer months was about

normal with no very high records. The hay crop was heavy and nearly all early cut fields gave a large second crop. September and October brought mild weather and the conditions were most favorable for harvesting. The first light frost was on September 18th and the first killing frost September 28th. The growing season was therefore 159 days, from the last severe frost in the spring. The average growing season at this Station for the past ten years has been 146 days.

Through the kindness of the New England Meteorological Society we are able to publish the rainfall records from thirteen of their stations in Connecticut. Table 61 gives the rainfall as recorded for the six months ending October 31st for twenty-one localities in the State, and table 62 gives the summary of observations made by the Station at Storrs.

TABLE 61.

Rainfall during six months ending October 31, 1897.

Locality.	Observer.	Inches per Month.						
		May.	June.	July.	August.	September.	October.	Total.
Falls Village, -	M. H. Dean, -	3.73	5.22	10.57	4.77	3.81	.78	28.88
Cream Hill, -	C. L. Gold,* -	4.22	5.15	9.71	5.28	2.85	1.04	28.25
Norwalk, - -	G. C. Comstock,*	7.34	2.67	10.12	3.15	2.24	1.79	27.31
Bridgeport, - -	Wm. Jennings,* -	6.62	3.41	18.77	4.11	1.97	2.11	36.99
Waterbury, - -	N. J. Welton,* -	5.34	3.77	18.10	3.51	2.18	1.08	33.98
Canton, - -	G. J. Case,* -	4.96	4.92	16.96	6.56	2.09	1.14	36.63
West Simsbury, -	S. T. Stockwell, -	4.74	4.82	16.45	5.09	1.82	1.13	34.05
Southington, -	Lumen Andrews,*	5.50	4.55	19.90	6.33	2.65	.85	39.78
New Haven, -	Weather Bureau,*	5.03	2.47	10.03	6.81	2.42	1.25	28.01
Newington, - -	J. S. Kirkham, -	5.46	4.18	13.71	5.53	2.10	.57	31.53
Hartford, - -	Prof. S. Hart,* -	5.85	3.83	—	5.46	2.33	—	—
Windsor, - -	H. H. Moore,* -	5.47	4.53	15.29	8.19	1.56	.54	35.58
Vernon, - -	E. H. Lathrop, -	5.04	4.25	11.68	5.49	4.15	—	—
So. Manchester, -	K. B. Loomis, -	5.24	3.20	11.88	6.13	2.15	1.09	29.69
Middletown, -	C. W. Hubbard,*	5.00	3.52	13.35	7.12	2.44	1.15	32.58
Madison, - -	J. D. Kelsey, -	4.51	3.47	9.53	5.27	2.54	.88	26.20
New London, -	Weather Bureau,*	4.76	2.48	6.22	5.06	3.74	1.20	23.46
Colchester, - -	S. P. Willard,* -	5.01	2.64	10.82	8.67	2.85	1.37	31.36
Lebanon, - -	E. A. Hoxie, -	4.47	2.85	9.75	8.00	2.68	—	—
Storrs, - -	Experim'nt Station,	4.44	2.79	12.24	5.23	1.39	.92	27.01
Voluntown, - -	Rev. C. Dewhurst,*	4.46	3.66	8.53	5.58	1.82	.80	24.85
	Average, - -	**5.10**	**3.73**	**12.68**	**5.78**	**2.46**	**1.09**	**30.84**

* New England Meteorological Society observer.

TABLE 62.

Meteorological Summary for 1897.

OBSERVATIONS MADE AT STORRS BY THE STATION.

	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Mean.	Total.
Highest barometer, - -	30.74	30.64	30.87	30.62	30.37	30.30	30.36	30.20	30.42	30.66	30.61	30.58	30.53	—
Lowest barometer, - - -	29.22	29.58	29.22	29.46	29.67	29.61	29.62	29.62	29.81	29.60	29.22	29.33	29.50	—
Mean barometer, - - -	30.04	30.08	30.03	30.08	29.97	29.95	29.98	30.00	30.13	30.16	30.06	30.07	30.05	—
Highest temperature, - -	53	46	62	78	81	83	89	81	89	86	64	59	73	—
Lowest temperature, - -	−2	4	2	19	37	41	53	46	32	25	5	3	22	—
Mean temperature, - - -	25	27	34	46	56	62	69	66	60	51	39	31	47	—
Relative humidity, - - -	—	—	—	65	70	74	87	84	77	71	—	—	—	—
Total precipitation, - -	3.84	3.40	3.66	2.37	4.44	2.79	12.24	5.23	1.39	.92	7.14	5.61	—	53.03
Number of days with precipitation of .01 inch or more,	9	7	11	9	13	7	13	9	6	4	15	13	—	116
Number of clear days, - -	10	10	9	8	5	8	7	10	14	16	7	6	—	110
Number of fair days, - -	10	11	11	12	9	10	10	16	12	7	9	13	—	130
Number of cloudy days, - -	11	7	11	10	17	12	14	5	4	8	14	12	—	125
Total movement of wind in miles,	6460	6487	8248	7284	6633	5853	4637	4204	5398	6189	8226	7015	—	76634
Maximum velocity of wind, -	50	48	50	40	30	30	36	40	40	40	60	54	—	—

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Report No. **1**, 1888; Report No. **2**, 1889; Report No. **3**, 1890; Report, No. **4**, 1891; Report No. **5**, 1892; Report No. **6**, 1893; Report No. **7**, 1894; Report No. **8**, 1895; Report No. **9**, 1896; Report No. **10**, 1897.